NT GENERATOR PERFORMANCE STANDARDS CODE REVIEW

Technical advice

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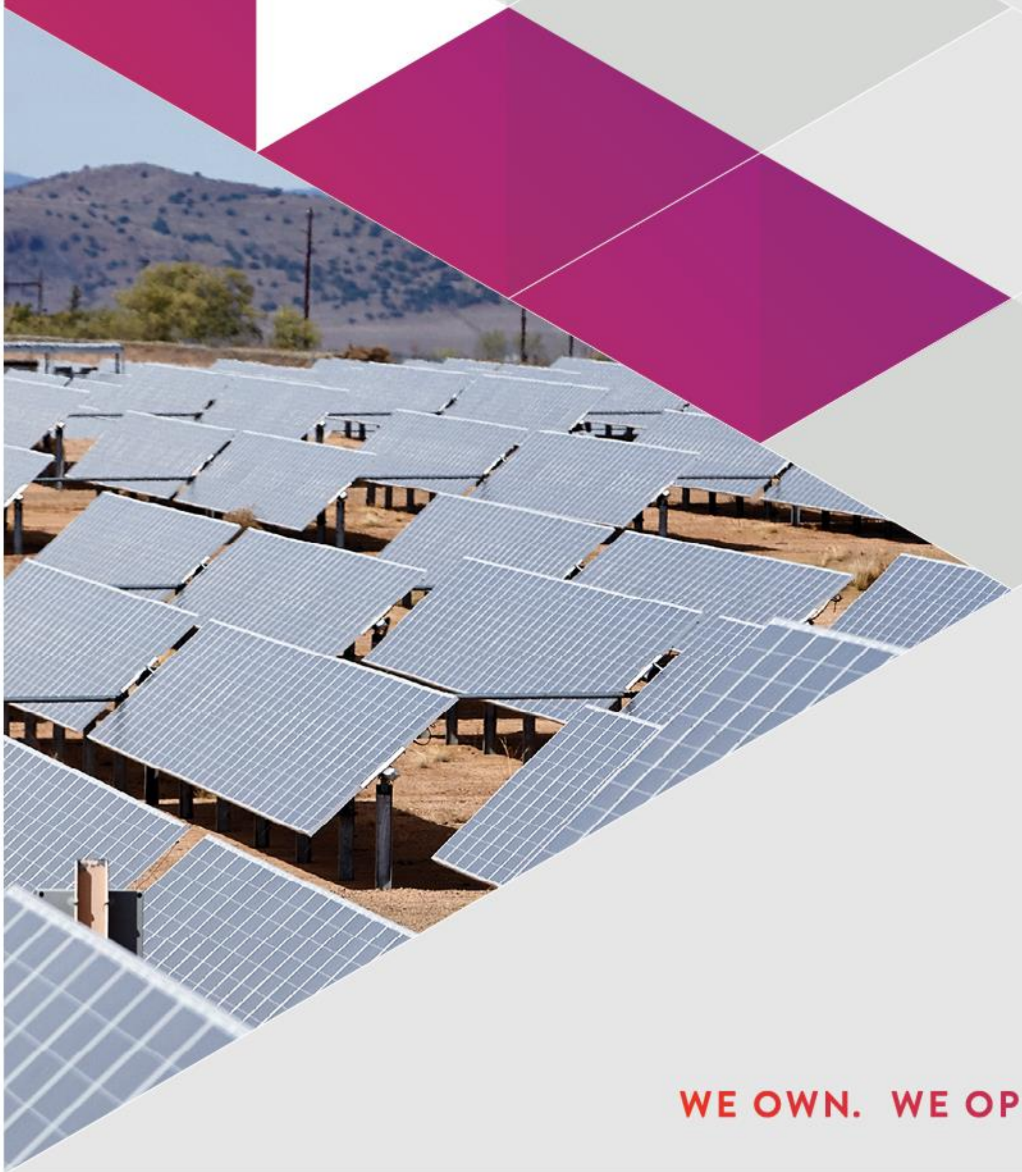
Prepared by Hydro-Electric Corporation
ABN48 072 377 158

t/a Entura 89 Cambridge Park Drive,
Cambridge TAS 7170 Australia



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	(name)	(signature)	(date)
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1. Introduction

NT Power and Water Corporation (PWC) engaged Entura to provide review of the technical basis of their proposed rule changes for new generator connections. The proposed rule changes incorporate generator performance standards adapted from the National Electricity Rules into the Network Technical Code as well as forecasting requirements designed to safeguard network reliability

Entura have reviewed PWC's proposed approach and in our view this approach is technically achievable and does not present a major barrier for developers.

1.1 Scope of work

The scope of work PWC requested is provided below.

1. Verify analysis of the technical feasibility for solar forecasting and reasonableness of the solar forecasting accuracy modelling approach and assumptions.
2. Verify analysis of energy to capacity forecast conversion modelling and validate associated assumptions and data sources, including the appropriateness of battery sizing and specifications.
3. Verify the appropriateness of battery provision assumptions both technical and costing in the NT context, including:
   (a) Centrally located battery, including inverter; or
   (b) Battery located at point of generation behind the inverter (ie DC connection with no inverter costs).
4. Provide an opinion on the technical feasibility of all the equipment (hardware and controls) to achieve the capacity forecast obligation. Ie – current technology. Eg - a battery to do the required duty of capacity forecasting – capital cost, asset life, degrading capacity vs time, control system to respond to local change in PV output, etc
5. Verify if frequency control (a droop characteristic) on inverters is a standard functionality generally available or would introduce additional cost to generator projects. Advice on the extent of commissioning time and indicative cost for demonstrating capability (if readily able to quantify).
6. Verify the inverters / solar farm can simultaneously supply the required reactive power control range at all levels of active power output (ie it’s not one or the other or simply "power factor").

2. Solar forecasting

2.1 Solar forecasting and dispatch approach

PWC’s proposed forecasting requirement for new generator applications are provided in Appendix A. Entura has reviewed PWC’s technical basis for these requirements, and their assumptions of costs to proponents and makes the following comments.

Technical solutions are readily achievable that can meet the PWC requirement and firm the plant output on a 30 minute look-ahead basis, to ensure 15 second output does not drop below a nominated dispatch value.

Entura is confident that the hardware and controls necessary to meet forecasting obligations are available, mature, and experience exists in their use, and that there are no technical barriers to this approach. However, it is clear that the forecasting requirement will require changes compared to a conventional PV plant design and / or operation, which will have cost implications for these projects.

There are various options available to developers that could achieve the proposed requirements, and there is scope for flexibility. PWC proposed approach is seen to be technology agnostic, and proponents can evaluate a number of solutions as part of developing a compliant project design. Entura has considered the following solutions in forming its opinion:

- A 'conventional' solution with an AC coupled battery energy storage system (with bi-direction power conversion unit) and conventional solar forecasting technology:
  - Entura has checked PWC modelling and confirms that with an appropriately sized battery, this can allow firming of a solar plant output over each 5 minute interval of the 30 minute forecast.
  - Meeting the forecasting requirements entails very high power to energy ratio that would likely necessitate significantly oversizing conventional lithium ion batteries.
- Alternatives solutions including:
  - DC coupled battery storage arrangement as above (with inverter and DC-DC converter in place of the bi-directional power conversion unit)
  - DC or AC coupled alternative storage arrangement (e.g. flywheel or supercapacitor) to achieve higher power to storage ratios commensurate with the forecasting requirements.
  - Not installing any storage and forecasting minimum expected production for each 5 minute interval (accepting a level of curtailment in difficult to forecast conditions).
  - Purchase / contract of any of the above services from other projects, conventional generators, or dedicated service providers.

All of the above are considered technically viable. As proponents develop experience in their application, it is expected that initial forecasts may be conservative, but subsequently tuned to reduce conservatism.

Entura has reviewed PWC's estimates of the cost implications for the range of above solutions and compared these against our internal databases of current market costs for storage and associated plant. The expected cost (or revenue equivalent reduction) of meeting the forecasting requirement is estimated in the order of about \$320-480/kW_{ac} of PV installed or 20-30% of the cost of the solar PV plant, plus a similar ratio of ongoing operations and maintenance cost. The upper end is represented by the 'conventional' solution. Viability will then depend on market price of energy, however, Entura does not expect this cost increment to be prohibitively high.

Additional considerations

Depending on the approach selected, proponents may need to offer conservative forecasts to meet the forecast requirements at the required frequency. Less conservatism is required with larger energy storage to power ratios, as the energy storage can be used to balance dispatch and forecasts over periods longer than 30 minutes. These effects contribute to the additional costs expected for developers, and are considered in the above-mentioned estimates.

The PWC proposed approach considers the possibility that changes to forecasting requirements may be necessary as the system evolves. This is reasonable as it is not possible to predict how generation distribution and technology will be implemented over the medium term. However, this needs to be balanced against proponents need to have a high level of confidence to make long-term investment decisions. Any future changes to forecasting will need to be preceded by consultation and select an approach that does not unreasonably disadvantage active generators. Based on discussions with PWC, Entura understand that any such changes would follow the framework for changes set out in the regulations, requiring consultation with industry and approval by the regulator. Entura expect that this would result in infrequent changes and only where necessary to safeguard system reliability.

2.2 Centralised vs decentralised network support functions

The forecasting requirement is being introduced as a means for PWC to maintain system reliability and power quality under increased distributed renewable generation. The capability required to do this can be provided:

- Physically coupled with the new generation or stand-alone (at another, or 'centralised') location in the network
- As a service by the new generators (or their agent), or as a service by PWC (or other third party) and paid for under charges to new generator as part of costs of their connection.

The proposed forecasting requirement allows ancillary services to be coupled with new generation or at a stand-alone location, as a service by the new generators[1]. The alternative is for PWC to provide these services from a centralised location or at strategic network locations (but not coupled with new generation). Both models are considered technically feasible, however, there are associated advantages and disadvantages:

- A stand-alone battery approach to network support would effectively require the 'conventional' technology solution listed in Section 2.1. This corresponds to the high end of the identified cost bracket for the range of technology options.
- Installation of centralised support by PWC may occur out of sync with installation of new generation, resulting in inefficiencies and reliability risk.
- Calculation and attribution of use of system charges to account for PWC's costs in the stand-alone solution is complex and difficult to provide as a robust and transparent attribution to customers.
- There are likely to be benefits to voltage management on feeders as a result of smoothing energy flows and providing reactive power capabilities with distributed services, however, the batteries contemplated here with relatively short duration of storage would not necessarily make a significant contribution to this capability. The proposed batteries would improve voltage fluctuations as per IEC 61300-3-11, but Entura expect that the solar PV plant can be compliant with this standard without storage in most cases.

[1] Under the proposal, automatic access would apply for services that are physically coupled with generation, and negotiation under proposed NTC 3.3.5 would be required for services not physically coupled with generation.

- Coupling distributed storage with generation on radial feeders will not provide system security against a fault on that feeder. The extent of this issue will depend on the distribution of new generation.
- PWC's forecasting requirements inherently assume (as a worst case) that fluctuations in solar output due to weather occur simultaneously across all plants. This is conservative and typically spatial averaging results in less severe events, which may mean a PWC supplied centralised service is a more efficient option. However, PWC has considered likely clustering of sites and the need to prevent system wide cascading failure under worst case scenarios, and hence some conservatism is not unreasonable.

Considering the above, Entura supports the decentralised approach as allowing a transparent market based solution that is expected to achieve reliability requirements (subject to some network planning considerations) with higher likelihood of delivering a least cost solution.

3. Inverter capability

Utility scale solar inverters, such as those used in >2MW solar plants are able to provide grid support functionality sought by PWC, as discussed below.

Entura has based its view on its experience conducting grid connection studies under the NER for utility scale solar PV plants. These inverters have been assessed as meeting mandatory Australian Standards, and so are suitable for operation in Australia. It is noted that such inverters are outside the scope of AS/NZS 4777.2:2015 Grid connection of energy systems via inverters - Inverter requirements, which is limited to a maximum capacity of 200 kW. So while this standard requires capabilities of inverters in line with that sought by PWC, the grid support capabilities are assessed under the NER rather than AS4777. In Entura's experience utility scale inverters also meet and exceed the requirements of AS4777.

3.1 Frequency control

Automatic frequency control is available as standard for centralised grid inverters. Provision of power reduction (lower) in response to over-frequency is available in all cases. Raise capability is available when plant is installed with storage or where PV output is being curtailed from full possible output. Entura understands that the PWC automatic access requirement for new generators would be to have frequency control 'enabled'. Under PWC's definition of enablement:

- Enablement | Operational requirement (SCTC): If the System Controller requires a generator to be enabled for FCAS it will only supply it if it has the headroom (for raise) or floorroom (for lower) to do so. A generator operating at maximum output can be enabled for FCAS, but be unable to supply FCAS raise as it has no headroom. In regards to lower service, a generator can provide FCAS lower if it is enabled and it is dispatched above its minimum stable load.

This definition is consistent with Entura's view of the capability of typical inverter based solar PV plant. System Control could only call on raise capacity from systems with no storage if they were known to already be curtailed. A requirement for 'enablement' of automatic frequency control is expected to add no significant additional cost to a typical inverter solution in the market now.

3.2 Reactive power control

Reactive power control capability is available as standard for large grid inverters and can act concurrently with automatic frequency control. Inverters are typically limited to maximum apparent power levels so increasing reactive power requirements reduces active power capability. This is not considered a barrier and this behaviour is currently anticipated in the NER and proposed PWC alignment with these rules

A reactive power requirement aligned with the NER (0.395 of rated active power) is not considered onerous and is currently being achieved by projects in the NEM as part of the automatic access standard for new connections. It will be important to take into account that the requirement is applied at the point of connection and additional reactive loads occur between inverter and point of connection, meaning effective power factor at the inverter at full output will be dependent on the plant design. In some instances, addition of reactive plant may be warranted rather than sizing of inverter capacity to meet requirement.

A reactive current cap during contingency events of 1.0 x active rated power is likely to be achievable (without adding reactive plant). Inverters are typically capable of providing 1.2-2.0 x active rated power under overload conditions. However, if this requirement is applied at the point of connection, taking into account reactive loads between the inverters and point of connection, the effective maximum reactive current is reduced from the inverter capability. In some cases, addition of reactive plant may be warranted to meet this requirement.

A requirement for reactive power control is expected to add minimal to no additional / incremental cost. If however reactive plant is required to be installed, this may add additional project cost above that considered for solar forecasting requirements.

4. Conclusion

Forecasting requirements proposed by PWC have been assessed by Entura for their implications on solar PV generators. Entura supports the view that mature technical solutions are available to meet these requirements. Likely cost (or revenue) implications for generators is estimated in the order of about $320-480/kW$_{ac}$ of PV installed or 20-30% of the cost of the solar PV plant, plus a similar ratio of ongoing operations and maintenance cost.

Placing this requirement on generators, rather than PWC undertaking this function as a system service provides more flexibility and opportunity to innovate and a higher likelihood of least cost solutions. There is potential for some system security risk of locating ancillary services on radial feeders, which may be managed through network planning.

Other network support capability for enabling automatic frequency control and reactive power support (up to identified limits consistent with the NER) are considered to be achievable by typical utility scale inverters.

Appendices

A PWC proposed requirements

3.3.5.17 Capacity Forecasting

(a) In this clause 3.3.5.17, the following terms apply:

(1) 't' is time.

(2) 't=0' refers to the moment when a forecast is updated.

(3) 't=[numeral]' refers to the number of minutes elapsed since t=0.

(4) 'capacity' means the minimum capability of a *Generating System* to deliver an active power output at a continuous steady level over the relevant 5 minute interval.

(5) 'firm offer' means the capacity forecast provided at t=0 for the interval commencing t=0 for 5 minutes

(6) 'dispatch capacity' means the capacity instructed to the *Generator* to be injected into the grid.

(7) 'actual capacity' means the minimum instantaneous power injected into the grid for the interval commencing t=0 for 5 minutes, or the dispatch capacity, whichever is the lower.

(b) The capacity forecasting automatic access standard is:

(1) A *Generator* must supply to the *Power System Controller* a forward forecast of the capacity of its *Generating System*.

(2) The forecast in 3.3.5.17(b)(1) must:

(i) include a 24 hour ahead forecast for capacity for every 5 minute interval, updated at 5 minute intervals; and

(ii) have an accuracy such that in any rolling 24 hour period at 90% of the non-zero forecasts for the intervals commencing from t=5 to t= 30 do not exceed the actual capacity for the time for which the forecast was made.

(3) For the 10% of forecast updates that do not meet paragraph (2)(ii) above, the forecast must not exceed the actual capacity by a margin greater than:

(i) 5% of the *Generation Unit's* nameplate rating; or

(ii) 1 MW,

whichever is the lesser.

(c) A *Generator* must provide forecasts to the *Power System Controller* in a format specified by the *Power System Controller*.

(d) The *Generating System* owner will be required to report compliance against the above requirements in a format and timeframe determined by the *Power System Controller*.

(e) In the event of non-compliance with the automatic access standard by a *Generator*, the *Power System Controller* may adjust that *Generator's* subsequent forecasts and firm offers accordingly.