1. Background

Tonga Power Ltd currently has no standard on supply security. This paper intends to introduce the concept of security of supply to the Board of Directors (from a power generation point of view, excluding network security) and proposes a security standard for each of the four island systems.

Security of supply ensures enough FIRM generation capacity is available to meet consumer demand. Firm so that it ensures generation is always available for dispatch at short notice to cover faults or to meet sudden changes in consumer demand.

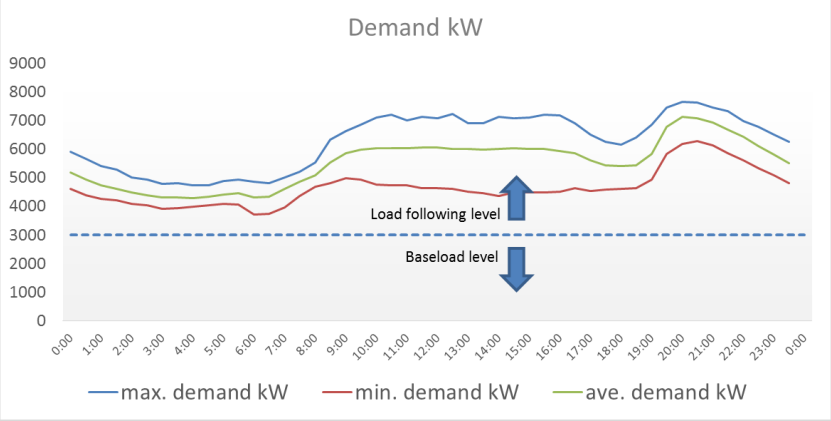
Intermittent (or unpredictable) generation capacity can be available but it cannot be relied on as the output depends on variable fuel sources such as solar or wind energy. Intermittent generation can be made firm and used for anytime despatch if it is associated with bulk energy storage like batteries.

A utility always needs adequate capacity so that supply can meet consumer demand at any given time, including when other generators fault.

2. Demand and Number of Generators

Tonga's demand for power is low enough that power can be transmitted out to the consumer from a single site. Making it easy to invest in low cost diesel power generators.

Generators can be defined as *load following* or as *base load*. Because demand is defined by consumer behaviour, demand varies significantly during a 24 hour period, and while base load generation runs at the most efficient point of output for a generator, the load following generation ensures the "slack" in demand is always met. The diagram below shows how these two types of generation support one another.



The generation available at any time must be sufficient to meet demand at any time, and this means additional generation capacity is always available but not used. This is called *spinning reserve*. Spinning reserve is a level of redundancy that exists purely to ensure customer supply is not interrupted.

The level of spare capacity available at either immediate notice or at short notice is what is defined in the security policy. The security policy reflects the implications of an outage, balancing the level of nuisance or cost to a consumer (e g a home owner might miss some TV time, Tonga Forest Products might lose order for sawn timber). Balanced against this is the cost of providing a secure supply. If a more secure supply doubles the tariff then customers will be happier with the occasional outage.

Therefore a power station may have spare capacity in running generators (spinning reserve, e g where a generator is only 50% loaded), or it may have back-up generation that is available after a period of outage (our proposal for a mobile generator that can be connected in emergencies within say one day is a good example, or the LDS generator that can be operational in five minutes)

3. Security of supply

The term refers to the policy that ensures there is enough capacity to meet demand at short notice or after an acceptable interruption. The acceptable level of security of supply is defined by:

- Meeting the demand curve at any time.
- Availability of resource in the country. For example diesel storage is readily available in Tonga.
- Operating and fuel costs in maintaining extra capacity on-line in case it is needed.
- Investment costs in back-up generation.

Balancing the cost factors as defined above, the probability of outage and impact of an outage needs to be understood:

- What is the probability of a major fault, triggering the risk of TPL running out of generation capacity – immediately and after a short or longer period)?
- What availability rate can TPL afford and not cause an unacceptable customer or stakeholder reaction?

If the response is that TPL cannot afford a failure at any time, then the concept of *N+1 redundancy* needs to be introduced and ideally supported by regulation.

4. N+1 Redundancy

N+1 redundancy is a form of resilience that ensures system availability in the event of component failure. By duplicating critical components of a whole system, the whole system can be seen as fail safe.

N in this case, is a system that meets a given task. Adding the numerical one (1) is a reference to replicating the most critical component in the system.

There are several ways to look at N+1 redundancy. An entire power station can be duplicated and located at a different location (if the impact of say an earthquake is unacceptable). However, no small power utility can afford such an undertaking.

From the point of view of this policy, n+1 redundancy refers to duplicating the *largest generator* in each of TPL's four power stations. The policy assumed intermittent generation (solar and wind) cannot be relied on at any time and are excluded.

5. Proposed Generation Security of Supply Policy

The proposed policy for each of the four island systems is outlined below. The policy is not based on exhaustive analysis or customer surveys, it is based on history of operation and managing our total cost of generation.

Tongatapu**:** propose N+1 security

Popua power station has 6 X CAT 3516 (each at 1,400 kW) and 1 X Mak 6CM32 (2,800 kW) diesel generators.

A second Mak 6CM32 will be commissioned late May 2014, after which two (2) X CAT 3516 diesel generators are planned for decommissioning soon after (probably be kept serviceable as a back-up).

The largest contingency outage is when an Mak 6CM32 experiences a fault, sustained over a long period of time, or is unavailable when it is out for extended overhaul.

N+1 means we have to have this much spare capacity available. There is a risk of further outage if one Mak is unavailable, but we believe that the risk of this is small and we have access to the likes of the LDS Liahona generator for back-up.

N+1 security is proposed.

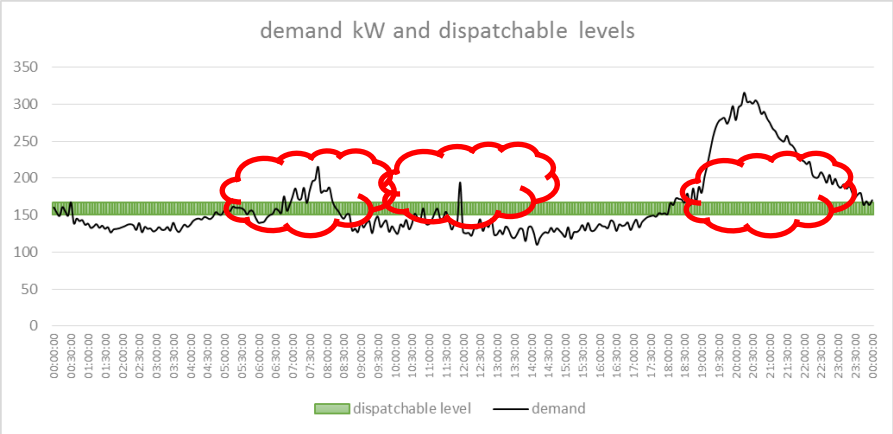
***Vava'u*: propose N+1 security**

At Vava'u the customer base and size of the demand makes it worthwhile proposing an N+1 security level. This means that if one of the two 600 kW Cummins diesel generators were to be out of service, the other generators can carry the demand at any time.

***Ha'apai and 'Eua:* propose N security, for up to 48 hours**

'Eua power station is an example of a station that has no redundancy. The power station has limited choice as there are only 2 x Cummins L10, each rated at 187 kW.

However, if one generator were to sustain a major fault for a long period of time (as happened at the beginning of 2013), the following diagram shows that on this particular day demand exceed supply on three occasions.



When a single generator fails in 'Eua for a long period of time, a rolling load shed program will be called upon. During the peak hours, up to 50% of consumer demand is lost.

While it is not a common occurrence, it is deemed acceptable given the cost of generation for the small customer base.

At Ha'apai we have two 187 kW generators installed, in addition we have a 300 kW lease generator. It is proposed that same N security policy apply at Ha'apai as at 'Eua. This means over time the lease generator can be dispensed with, reducing our operating costs.

It does mean that customers can experience load shedding if one generator fails and the lease generator is not available any more.

6. Future Back-up Generation

A proposal has been put to the board at this meeting, for the procurement and construction of a trailer mounted mobile generator. It is intended that this generator would be used primarily as a back-up unit for 'Eua and Ha'apai. This means the generator (at 300 kW) can provide a level of security that ensures all demand on an island is met if a generator fails but subject to a delay of around 48 hours, while the mobile generator is shipped to the affected island. Rolling load shedding at peak times would have to take place in the meantime.

Future intermittent renewable generation will not provide firm capacity, but reduce the risk supply shortage as at some time a diesel generator failure will coincide with a solar plant or wind generator being on line and producing.