

Redefining N-1 Security:

Boosting Distribution Network Capacity Without Undue Risk

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1. Abstract

Electricity distribution networks are facing increasing pressure to connect new load, accommodate changing customer behaviour, enable distributed energy resources, and maintain secure supply without placing unnecessary cost pressure on consumers. Traditional N-1 security assessment remains a valuable deterministic planning tool, but in many cases it is applied using conservative assumptions that do not fully reflect actual asset capability, operating flexibility, customer demand diversity, or the contribution of distributed energy resources and demand side management.

This paper proposes a practical “Deterministic Plus” framework for improving N-1 security assessment in New Zealand distribution networks. The approach retains the deterministic planning principles familiar to network planners and operators, while introducing greater precision in how security limits and customer demand are defined, calculated and compared. Rather than treating N-1 security as a single binary pass/fail test, the framework distinguishes between the N-1 Security Limit, being what the network can deliver under the worst credible single contingency, and the Load to Compare, being the demand that must be supplied during that contingency.

The framework applies this comparison across three time-domains: instantaneous, extended time-bound, and steady state. This allows short-term equipment ratings, load shifting, distributed energy resource response, and demand side management to be credited where they can be demonstrated and operationalised. A pilot application at WEL Networks’ Tasman Substation showed that applying this method lifted the pre-contingent acceptable load from approximately 23 MVA to approximately 30 MVA, delaying a \$15 million capital project by seven years and delivering an estimated NPV benefit of \$5.7 million.

2. Introduction

N-1 security has long been a cornerstone of electricity network planning. It provides a simple and robust framework for ensuring that customers can continue to be supplied following the credible loss of a network element. The approach has served the industry well by delivering a common planning methodology and a consistent basis for investment decisions.

Historically, network planners have had limited visibility of individual customer demand, network power flows and asset performance. Asset data was not always complete or reliable, and the real-time operating state of the wider distribution network was often only partially visible. In that environment, conservative assumptions, safety margins and rules of thumb were both necessary and appropriate. They provided a practical way to manage uncertainty and maintain network security when the true capacity of assets and networks could not be confidently quantified.

Today, distribution networks operate in a fundamentally different environment. Traditional SCADA systems are now complemented by widespread smart meter deployment, advanced analytics and improved monitoring technologies, providing much greater visibility of network performance and customer demand across the network. Network operators now have a more accurate understanding of asset capability, power flows and customer behaviour than was possible when many planning standards were developed. At the same time, distributed energy resources (DER), demand side management (DSM) and increasingly flexible network operating practices provide new tools for managing network constraints. Together, these capabilities allow previously unrecognised asset and network capacity to be quantified, accessed and utilised while maintaining acceptable levels of risk.

This paper proposes a practical enhancement to traditional deterministic planning. It introduces a time-bound framework for defining N-1 security limits and a supporting network planning methodology that better reflects how modern electricity networks perform and are operated in practice. The framework retains the simplicity and transparency of deterministic planning while enabling network businesses to safely unlock inherent asset and network capacity, improve investment timing, and integrate operational flexibility, DER and DSM into security assessments in a structured and auditable manner.

3. The Core Concept

The key insight is that N-1 security is not a single calculation but the comparison of two independent quantities:

1. The N-1 Security Limit

The maximum load the network can support under the worst credible single contingency (what the network can deliver).

2. The Load to Compare

An accurate estimate of customer demand that must be supplied during a contingency (what must be served).

A network is N-1 secure when the Security Limit exceeds the Load to Compare. In the past, calculations have used the steady-state limit of equipment and the maximum demand (or a percentile of peak load). This paper proposes three time-domains and true engineering limits.

4. The Deterministic Plus Framework

The Deterministic Plus framework applies the N-1 security assessment across three time-domains. Each time domain has its own N-1 Security Limit and Load to Compare.

4.1 Instantaneous

The instantaneous assessment considers the period immediately following a contingent event.

At this point, there has been no opportunity for operator intervention, load shifting, network reconfiguration, DER response or demand side management. The network must be capable of safely carrying the post-contingent load without exceeding instantaneous equipment limits.

This assessment defines the maximum load that may exist on the network at any time.

4.2 Extended Time-Bound (Four-Hour Limit)

The extended time-bound assessment considers what the network can sustain over a defined period, typically four hours.

For short periods of time, many assets can safely operate above their steady-state limits. This means the network can sustain a higher load for a limited duration following a contingency than it can continuously.

The Deterministic Plus framework recognises this additional short-term capacity and uses it to safely operate the network at higher pre-contingent load levels. Following a contingency, predefined operational actions such as network reconfiguration, load shifting, DER response or demand side management are used to reduce loading to the steady-state limit within the defined operating period.

The available short-term capacity therefore creates operational flexibility while maintaining deterministic security standards.

4.3 Steady State

The steady-state assessment considers the load and network limit for periods beyond four hours. This is the traditional N-1 limit. Following a contingent event, a Zone Substation's load will need to be reduced to the steady state limit. The load that is compared to the steady state limit is the maximum four-hour load.

5. Network Planning Methodology

The Deterministic Plus framework can be applied through a four-step planning process. The process is used to determine the N-1 Security Limits and corresponding "Load to Compare" for each time domain and to establish the operational actions required to move from a contingent state to a secure steady-state condition.

Step 1: Determine Asset Limits

Asset limits shall be established for all significant assets within the supply path to the Zone Substation.

For each asset determine:

- Instantaneous Asset Limit
- Four-Hour Winter Limit
- Four-Hour Summer Limit
- Steady-State Winter Limit
- Steady-State Summer Limit

The assessment shall include both the Zone Substation and its upstream supply assets. The limiting asset for each time domain establishes the corresponding Security Limit.

The output of this step is a set of asset limits for each time domain.

Step 2: Determine Existing Load

Determine the Loads to Compare for each time domain.

Extract at least one year of historical load data and determine:

- Maximum instantaneous load
- Four-hour rolling average load
- Seasonal demand characteristics

The output of this step is a set of Loads to Compare for each time domain.

Step 3: Determine Response Capability

Determine the load that can be reduced or transferred within each time domain.

Immediate Response Capability (within one minute)

Identify any load that can be automatically reduced or disconnected within approximately one minute following a contingent event. Examples may include:

- Automatic load control schemes
- Ripple control

- Protection-based load shedding
- Fast-acting DER response

This capability is used to establish the Instantaneous Security Limit.

Instantaneous Security Limit = Four-Hour Security Limit + Immediate Load Reduction Capability subject to not exceeding the Instantaneous Asset Limit.

Four-Hour Response Capability

Determine the load that can be reduced or transferred within four hours through:

- Network reconfiguration
- Feeder transfers
- Planned load shifting
- DER response
- Demand Side Management

The objective is to identify sufficient actions to reduce loading from the Four-Hour Security Limit to the Steady-State Security Limit.

The output of this step is a quantified response capability for each time domain.

Step 4: Establish Operating Tactics

Once Security Limits and Response Capabilities are known, operating tactics can be established.

Pre-Contingent Operation

A Zone Substation may operate above its Steady-State Security Limit provided the following criteria are met:

- The Zone Substation may operate at the Steady-State Security Limit plus available Four-Hour Load Reduction Capability, up to a maximum of the Four-Hour Security Limit.
- The Zone Substation may operate above the Four-Hour Security Limit by the amount of Immediate Load Reduction Capability, up to a maximum of the Instantaneous Security Limit.

This creates three operating bands:

Operating Range	Requirement
Up to Steady-State Security Limit	No action required
Steady-State Security Limit to Four-Hour Security Limit	Four-Hour Load Reduction Capability must be available
Four-Hour Security Limit to Instantaneous Security Limit	Immediate Load Reduction Capability must be available

Post-Contingent Operation

Following a contingent event:

Immediate Period

- The network remains below the Instantaneous Security Limit.
- Immediate load reduction capability operates where required.

Four-Hour Period

- Operators implement predefined actions such as feeder load transfers, DSM or DER response.
- Loading is progressively reduced towards the Steady-State Security Limit.

Steady-State Period

- The affected Zone Substation load is reduced to the Steady-State Security Limit within four hours.
- The network returns to a sustainable long-term operating condition.

The operating tactics convert short-term asset capability and network flexibility into safe and usable network capacity while maintaining deterministic security standards.

5. WEL Networks Case Study: Tasman Substation

WEL Networks has undertaken a pilot study of the new Deterministic Plus Framework at its Tasman Substation. Tasman was selected due to an emerging N-1 capacity constraint and the significant cost associated with traditional augmentation options.

At the time of assessment, Tasman Zone Substation was approaching its traditional N-1 limit. Several options had been identified to defer investment, including:

- installation of a battery energy storage system;
- permanent load transfers;
- increased load control.

When assessed individually, none of these initiatives were sufficient to defer the planned augmentation. However, when the Deterministic Plus methodology was applied, the assessment identified additional network capacity that was not recognised under the traditional N-1 methodology.

The methodology compared forecast load against three separate security limits:

- the Steady-State Security Limit;
- the Four-Hour Security Limit;
- the Instantaneous Security Limit.

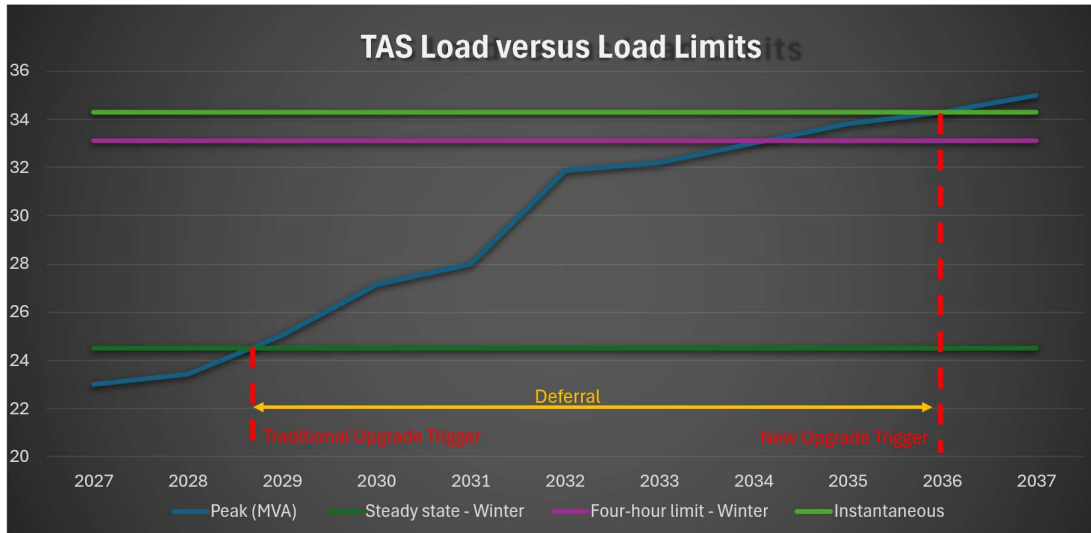
Under the traditional approach, the upgrade trigger occurred when forecast load crossed the steady-state limit. Under the Deterministic Plus framework, the relevant planning trigger moved to the point where forecast load crossed the four-hour limit, provided sufficient operational response was available to reduce loading to the steady-state limit following a contingency.

The difference between the four-hour limit and the instantaneous limit provides an additional operating buffer. This buffer recognises immediate load reduction capability and confirms that the network can remain within instantaneous equipment limits at the point of contingency.

Figure 1 illustrates the impact of this revised assessment. The traditional upgrade trigger occurs when peak forecast load (or 99 percentile) first exceeds the steady-state limit. The revised trigger occurs when the four-hour load forecast reaches the four-hour limit or the peak load matches the instantaneous limit.

Forecast load is compared against steady-state, four-hour and instantaneous security limits. The revised methodology defers the upgrade trigger from the steady-state crossing to the peak load crossing.

The Deterministic Plus assessment increased the acceptable pre-contingent loading from **24.5 MVA to 34.3 MVA**. This delayed the requirement for a major substation upgrade by approximately **seven years**. Based on WEL's investment forecasts, this represented the deferral of a **\$15 million capital project** and a net present value benefit of approximately **\$5.7 million**.



Importantly, these benefits were achieved without reducing security standards. The additional capacity was supported by quantified asset limits, defined response capabilities and documented operating tactics.

The Tasman case study demonstrates that significant customer value can be created through improved planning methodology alone. Rather than changing the underlying N-1 principle, the Deterministic Plus framework applies the principle with greater precision by recognising the time-dependent capability of network assets and the operational flexibility available within modern electricity networks.

6. Benefits

The Deterministic Plus framework delivers three key benefits for network businesses and consumers.

6.1 Improved Affordability

The primary benefit of the framework is the ability to safely utilise inherent asset and network capacity that is often hidden by conservative planning assumptions. By recognising time-bound capability and operational response actions, network businesses can defer unnecessary augmentation while maintaining established security standards.

This results in lower capital expenditure requirements and improved affordability for consumers.

6.2 A Practical Pathway for DER and DSM

The framework provides a structured and auditable method for recognising the contribution of Distributed Energy Resources (DER), Demand Side Management (DSM), load control and load shifting within N-1 planning assessments.

Rather than being treated as qualitative considerations, these resources become measurable and quantifiable components of network security planning.

6.3 Robust and Defensible Investment Decisions

The framework replaces broad safety margins and engineering rules of thumb with a more explicit assessment of network capability and operational flexibility.

By quantifying short-term asset capability, immediate response actions and four-hour response actions, network businesses can make investment decisions based on demonstrated engineering limits and documented operating tactics rather than conservative assumptions alone.

This improves the transparency, repeatability and defensibility of network planning decisions.

7. Conclusion

N-1 security remains a fundamental principle of electricity network planning. Historically, conservative assumptions, safety margins and engineering judgement were necessary because planners had limited visibility of customer demand, network loading and asset capability.

Today, smart meter data, advanced analytics, improved monitoring and greater operational flexibility provide a far more accurate understanding of both network capability and customer demand. This creates an opportunity to safely unlock inherent asset and network capacity while maintaining established security standards.

The Deterministic Plus framework retains the simplicity and transparency of deterministic planning while introducing a time-bound approach to N-1 security assessment. By separating the N-1 Security Limit from the Load to Compare and applying these assessments across instantaneous, four-hour and steady-state time domains, the framework provides a more accurate representation of how modern distribution networks operate.

The WEL Networks Tasman Zone Substation case study demonstrates that significant customer value can be created through improved planning methodology alone. By recognising short-term asset capability, immediate response actions and planned operational response, the acceptable pre-contingent loading increased from approximately 23 MVA to 30 MVA, delaying a major augmentation project by approximately seven years.

This methodology does not relax N-1 planning principles. Instead, it applies them with greater precision by using true engineering limits, measured customer demand and defined operational response capabilities. The result is a practical and auditable framework that enables network businesses to make better use of existing assets, improve affordability for consumers and make more robust investment decisions.