PowerWater

Program Business Need Identification

Power and Water Corporation

CONTROLLED DOCUMENT

NMP7 / PRD33448

Darwin Distribution Substation Fault Level Replacement Program

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Proposed:

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Date: 15/2/2018

Approved:

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Date: 23/02/2018

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Date: 15/2/2018

Refer to email D2018/72353

Finance Review
Date: 06/02/2018

Refer to email D2018/65984

PMO QA
Date: 13/02/2018

1 Program Summary

Project Title:	Darwin Distribution Substation Fault Level Replacement Program		
Project No:	NMP7 / PRD33448	**SAP Ref:**	
Financial Year Commencement:	2019/20		
Business Unit:	Power Networks		
Project Owner (GM):	Djuna Pollard	**Phone No:**	08 8985 8431
Contact Officer:	Stuart Eassie	**Phone No:**	08 8924 5214
Date of Submission:	23/02/18	**File Ref No:**	D2017/360014
Submission Number:		**Priority Score:**	
Primary Driver:	Compliance Growth/demand	**Secondary Driver:**	Safety
Project Classification:	Capital Program of Works		

2 Recommendation

MAJOR PROJECT >$1M OR PROGRAM

It is recommended that Chief Executive note the proposed five year Darwin Distribution Substation Fault Level Replacement program, for an estimated budget of $4.64M, and approve the inclusion of this program into the SCI for this amount.

The forecast for this program of work extends beyond the current SCI period. The first two years of this program aligns with the last two years of the 2017-18 SCI. This program will be included in the 2019-24 Regulatory Proposal to the Australian Energy Regulator (AER).

Note that individual projects within the program will be documented in Business Case Category Cs to be approved by the Executive General Manager Power Networks.

3 Description of Issues

Power Networks owns and operates a fleet of over 4,000 distribution substations and associated switchgear across the four regions of Alice Springs, Darwin, Katherine and

Tennant Creek. Included in the fleet are 859 Magnefix MD4 (also known as Holec/Hazemeyer MD4) switches, most of which are installed within 11kV distribution substation enclosures in Darwin and Alice Springs as shown in Table 1 below.

Table 1 Substation and Switchgear Portfolio

Region	Distribution Substation Population	Magnefix MD4 Switchgear
Alice Springs	199	188
Darwin	1,297	670
Katherine	43	1
Tennent Creek	11	0
Total	**1550**	**859**

The Magnefix MD4 switchgear is a compact fully epoxy resin insulated Ring Main Unit for 12-15 kV distribution networks. It is equipped with load-break switches and fused load-break switches up to a 14.4 kA short circuit withstand. Development of the network over time has resulted in an increase of system three phase fault levels above 14.4kA in some areas of the distribution network. Currently the network contains 65 Magnefix switchgear installations where the system fault levels exceed or are encroaching on the equipment rating. As a consequence Magnefix switchgear no longer meets the minimum system fault levels. The risk of catastrophic equipment failure and the potential injury to workers and the public are key drivers for investing in the upgrade of the Magnefix switchgear.

Table 2 - Volume of Magnefix Exceeding or Approaching Rated Fault Level

Fault Level Condition	Magnefix Installations
Exceed equipment fault level by >15%	3
Exceed equipment fault level by up to 15%	3
Exceed equipment fault level by up to 10%	3
Exceed equipment fault level by up to 5%	7
At equipment fault level	11
Encroaching 5% of equipment fault level	12
Encroaching 10% of equipment fault level	15
Total	**54**

Other drivers for the investment include maintaining network reliability, compliance with the requirements of the Network Technical Code and Network Planning Criteria, worker safety and public safety.

The affected switchgear is mainly located in the Darwin region, with the majority installed in the CBDs of Palmerston and Darwin City. These areas are characterised by high pedestrian traffic, increasing the likelihood of interaction with the public and therefore the risk associated with switchgear failure. Figure 1 shows the location of the units exceeding fault level rating in the Darwin CBD.

Figure 1 – Location of Magnefix units exceeding fault level ratings in Darwin CBD

Figure 2 shows a unit exceeding fault level capacity installed in a high-traffic CBD location.

Figure 2 – High Traffic Location in Darwin CBD

The failure rate associated with Magnefix switchgear has been increasing as shown in Figure 3 and the consequences of these failures, while not yet resulting in injury, have raised concerns in relation to the portfolio's condition and changes to maintenance practices for units approaching end-of-life. The main failure modes observed are deterioration of the switchgear insulation due to harsh service conditions, and termination failures.

Magnefix is considered to have very poor operator safety as there is no barrier between operator and switchgear in the event of a switchgear failure or incorrect operation. All operations can only be performed manually with the operator standing directly in front of the switchgear. For additional details refer to the Distribution Switchgear Asset Class Management Plan.

In January 2017, 2 explosive failures associated with Magnefix switchgear resulted in distribution substation doors being blown open or dislodged, exposing the nearby area to the fault energy. Fortunately, no injury was recorded as there were no people in proximity to the explosion at the time of the failure. A detailed investigation[1] into the first event has identified a variety of contributing factors including age, operating environment, historical construction and maintenance practices and inherent design limitations. The asset management approach for this switchgear type is under review to determine the lowest cost option to manage end-of-life for the more than 800 units likely to be in service at the completion of this program.

[1] 20170328 Grace 3811- Investigation Report Magnefix Switchgear Failure

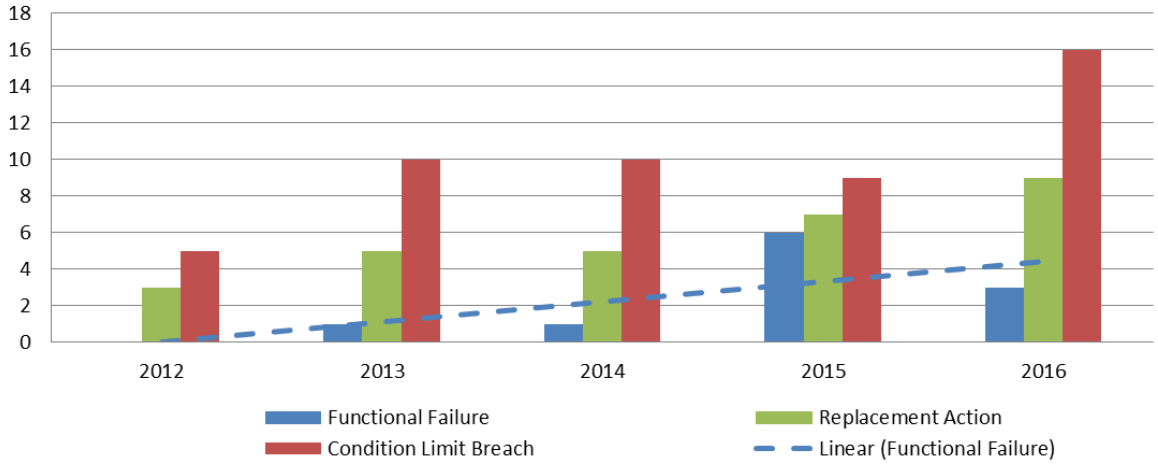


Figure 3 – Volume of Magnefix Failures Requiring Action

Project Needs

a. Safety

High voltage switchgear is generally reliable and performs well, however failures, though rare, can be catastrophic. Switchgear failure usually occurs at, or shortly after, operation of the equipment. The safe operation of high voltage switchgear depends firstly on the equipment specification meeting system requirements, and the equipment condition and operating environment.

Replacement of the Magnefix switchgear, where equipment ratings are being compromised, will address worker and public safety risk that currently exist. Given the assets at risk are in CBD areas, the likelihood of public interaction is elevated.

b. Compliance
The Network Technical Code and Network Planning Criteria requires PowerWater to comply with clause 15.4, that states: *For safety reasons, the fault rating of any equipment shall not be less than the fault level in that part of the network at any time and for any normal network configuration.* *As the system configuration is changed, fault levels may increase over time. New connections to the network shall therefore be designed with equipment fault level ratings reflecting modern standards that may exceed existing fault levels.* The Network Technical Code and Network Planning Criteria clause 15.4 (a) also states a minimum 20kA fault level for equipment to be connected to Power and Water's 11kV network. While Magnefix switchgear was installed prior to the code coming into effect, it is considered appropriate to apply this requirement to the small proportion of assets in areas of high pedestrian traffic.
c. Reliability (if not compliance obligation)
Configuration of the network to maintain fault levels within distribution equipment ratings is an abnormal operation of the network. Good electricity industry practice suggests that network configuration be based on the effective operation of the network to optimise capacity and system reliability. Replacement of the Magnefix switchgear, where equipment ratings are being compromised, will allow for the normal and effective operation of the network to maintain system reliability in CBD areas and improve customer outcomes.

4 Potential Solutions

The following options to maintain the safe and reliable operation of the network have been considered. These include:

Option 1 – Do Nothing

The do nothing option involves operating the affected assets above their rated fault level capacity.

This option does not mitigate the risk of catastrophic equipment failure and the potential injury to workers and the public, nor does it address the reliability implications of such failures.

Option 2 - Lower fault levels through augmentation

The distribution network is designed and operated as an open, meshed network of HV feeders run radially with open points. Fault levels are dependent on generation capacity and

zone substation (ZSS) transformer capacity. Generation capacity cannot be "designed" out of the network. Therefore to reduce fault levels, zone transformers with higher impedance are required. This would require significant investment in replacement of existing power transformers and additional zone substations to reduce individual transformer capacities.

This option would have an extraordinary cost and could not be implemented in an appropriate timeframe.

Option 3 - Network operational configuration

A network can be configured operationally to reduce fault levels, however this generally compromises reliability. Palmerston ZSS is currently being operated with a split 11kV bus to maintain the fault levels below distribution switchgear fault level ratings. This approach has resulted in significant outages to customers in the Palmerston CBD from minor faults in secondary systems associated with power transformers and switchgear. The contribution of zone substation (ZSS) failures to SAIDI has reduced substantially (Figure 4) as a result of improvements to maintenance practices since the 2008 Casuarina failure and the major replacement programs. However in 2016/17 a minor wiring fault caused a widespread outage to the Palmerston CBD which would not have occurred had the bus been in normal closed state, utilising the N-1 capacity of the zone substation. This failure accounted for the entire ZSS SAIDI contribution for 2016/17 and was a direct result of the network configuration to reduce fault levels.

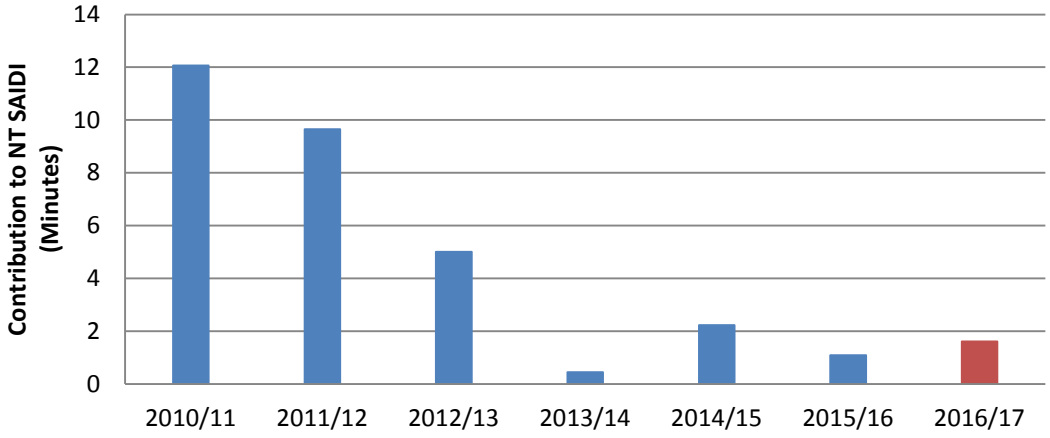


Figure 4 Zone Substation Failures Impact on SAIDI

A variation of this option is to manually split the 11kV for switching activities; however this only addresses the switching risk to operators and not the public risk. It also adds significant time to switching programs to manage load transfers between zone substations and buses, limiting availability of equipment for maintenance and inherently increasing the risk to operators as they are required to perform more network switching operations. It also increases cost due to the additional time required for switching.

Option 4 – Targeted Replacement of Substations Containing Magnefix Switchgear (Preferred Option)

Replacement of the compromised Magnefix equipment to augment the network for long term safe, reliable, and compliant operation. Magnefix is compact switchgear mounted in distribution substation enclosures. There is no equivalent sized switchgear available that could be mounted within the existing kiosk substation enclosure. As a result the distribution substation itself is replaced with current standard, including adequately rated switchgear.

While this option requires capital investment, this will be offset due to the distribution substations replaced being retained as spares for condition or failure based replacements in low fault current areas of the network. This will defer investment in new distribution substations in these areas.

Comparative Cost Analysis

A comparative cost analysis of the four options has been undertaken. The net present cost of each option including Opex and Capex over a 40 year period is detailed in the table below. The value of customer reliability and reduction in maintenance Opex has been modelled in the Net Present Cost.

Option	Capital cost ($M)	Net Present Cost ($M)	Comments
1 – Do Nothing	0.0	0.0	
2 – Network Augmentation	7.5	6.3	Assumes replacement of 5 power transformers at Darwin and Palmerston zone substations
3 – Operational Configuration	0.0	0.7	Includes estimated VCR impact of splitting 11kV buses
4 – Targeted Replacement	4.6	4.0	

As outlined above, Options 1 and 3 have the lowest capital cost and net present cost of the four options. However these options are not deemed acceptable for the reasons outlined in Section 3. Option 4 has the next lowest capital cost and net present cost.

Non-cost attributes

An analysis of the non-cost attributes for each option has been completed using the multi-criteria analysis method. The attributes are selected considering major risks and priorities to achieve Project Objectives. A weighting is allocated to each, totalling 100%. Each attribute is given a score out of 5 (from 1 – Fails to satisfy, to 5 – exceeds requirements); the score is then multiplied by the relevant weighting to give the weighted score that is summarised in the table below.

	Technical & System Risk		Stakeholder Risk	Commercial	
Criteria	Reliability	Compliance	Safety	NPC	Weighted Scores
Weighting (%)	15	30	40	15	100
Option 1	0.15	0.30	0.40	0.75	1.60
Option 2	0.75	1.50	1.20	0.30	3.75
Option 3	0.30	1.50	0.80	0.75	3.35
Option 4	0.75	1.50	1.60	0.45	4.30

As outlined above, option 4 has the highest non-cost attribute score.

Preferred Option

Option 4, replacement of the affected distribution substations with Magnefix switchgear is considered the prudent investment option. This option has the highest non-cost attribute score, and is the lowest cost option which adequately addresses the compliance and safety drivers.

The replacements will:

- Mitigate the risk of catastrophic failure and the risk to worker and public safety;
- Allow the effective operation of the network to maintain system reliability; and
- Address the non-compliance that currently exists under clause 15.4 of the Network Technical Code and Network Planning Criteria.

The forecast replacement volumes address the safety and reliability risk associated with the compromised switchgear currently in operation. Consideration will be given to addressing emerging fault rate issues during the next regulatory period. The volume forecast considers the risk associated with Magenfix switchgear encroaching fault rating to present a similar risk to those exceeding ratings due to the poor condition and hazards demonstrated by recent failures in low fault current areas. It also allows for replacements planned as part of the current condition based Distribution Substation Replacement Program[2] or other augmentation drivers.

[2] 2014 NPD – Power Networks Underground Distribution Substation Replacement Program BNI

Year	2019-20 Qty	2020-21 Qty	2021-22 Qty	2022-23 Qty	2023-24 Qty	Total Qty
Replacement volumes	8	8	6	6	6	**34**

Non-Network alternatives

Options 1 and 3 describes the only identified non-network alternatives. Option 3 has been implemented with demonstrated impacts on customer reliability for CBD customers in Palmerston and at an increased operational cost. This option is not considered an appropriate permanent solution.

Capex/Opex Substitution

No Opex solutions can reliably reduce the fault level of the network. Switching activities to split zone substation bus sections during operations incurs additional Opex costs. Note, an intensive maintenance program to arrest the increasing failure rate of Magnefix switchgear is also currently in development.

Contingent Project

This project does not qualify as a contingent project as defined by the NER Clause 6.6A.1. It is required for the continual safe and reliable operation of the network and is not contingent based on an external driver and does not exceed $30million or 5% of the forecast capital budget forecast.

5 Strategic Alignment

This program aligns with the Asset Objectives defined in the Strategic Asset Management Plan (SAMP) and Asset (Class) Management Plans (AMP). The capital investment into the Distribution Switchgear assets outlined in this program will contribute to the Corporation achieving the goals defined in the Boards Strategic Directions and SCI Key Result Areas of Health and Safety and Operational Performance.

6 Timing Constraints

The timing of the proposed program is based on the growth of the network beyond the capability of the switchgear to be safely operated. These assets are no longer fit-for purpose in their operating location but can be re-deployed to lower fault level areas of the network to maximise the remaining life of the distribution substation and switchgear. It is critical the program commences as proposed, which coincides with the completion of the Oil Ring Main Unit Replacement Program in 2018/19.

7 Expected Benefits

Driver	Benefit	Measure
Growth / Demand	Switchgear rating limitations eliminated	Quantity of switchgear exceeding fault rating.
Renewal / Replacement	Network safety	Health and Safety Index
Compliance	Improved compliance with the Code, Planning Criteria	Code Non-compliance
Service Improvement	Network reliability maintained	Performance against SAIDI and SAIFI targets
Commercial / Efficiency		
Social / Environmental	Public interaction	Public risk exposure

8 Milestones

Investment Planning	Project Development	Project Commitment	Project Delivery	Review
01/2018	NA	07/2019	06/2024	09/2024

The program delivery is scheduled to run over 5 years from July 2019 to June 2024. A program review will be held at the end of the 5 year program as well as interim reviews at the end of each Financial Year.

9 Key Stakeholders

Description	Title / Business unit
Internal governance stakeholders	Executive General Manager Power Networks
	Group Manager Service Delivery
	Chief Engineer
Internal design stakeholders	Senior Manager Network Development and Planning
	Senior Manager Contracts and Projects
	Senior Manager Asset Management
	General Manager System Control
External – Unions and public	Local Residents and Businesses
	ETU
	Ministers

External regulators	Utilities Commission
	Australian Energy Regulator

10 Resourcing Requirements

Not applicable. Resourcing requirements for this program are considered Business as Usual and will be incorporated into the development of Category C Business Case's for each individual replacement.

11 Delivery Risk

Site access for the removal and installation of equipment may need to be negotiated on a site by site basis. These negotiations could impact on the timely and effective delivery of the program. Early stakeholder notification and consultation would assist in managing the delivery of the program.

Consequential, site specific costs may result from works being undertaken on existing installations in existing built up environments. The expenditure estimates have been based on similar brown field works undertaken in recent years and is considered an average cost.

12 Financial Impacts

Expenditure Forecasting Method

The expenditure forecast has been based on a programmed approach. The forecast volumes focus on replacing the highest safety and reliability risk installations in the next regulatory period (2019/20 to 2023/24). Consideration will be given to addressing emerging fault rate issues during the following regulatory period.

Historical and Forecast Expenditure

No historical replacement of distribution substations due to fault level exceedance alone have been identified. Typically the assets in the highest fault level areas of Darwin and Palmerston CBD have been replaced through customer augmentation projects associated with network growth requiring upgrade to feeder capacity, new developments and upgrades to connection capacity. This has minimised the requirement for direct investment by PWC, however similar levels of growth and re-development are not expected in the next regulatory period.

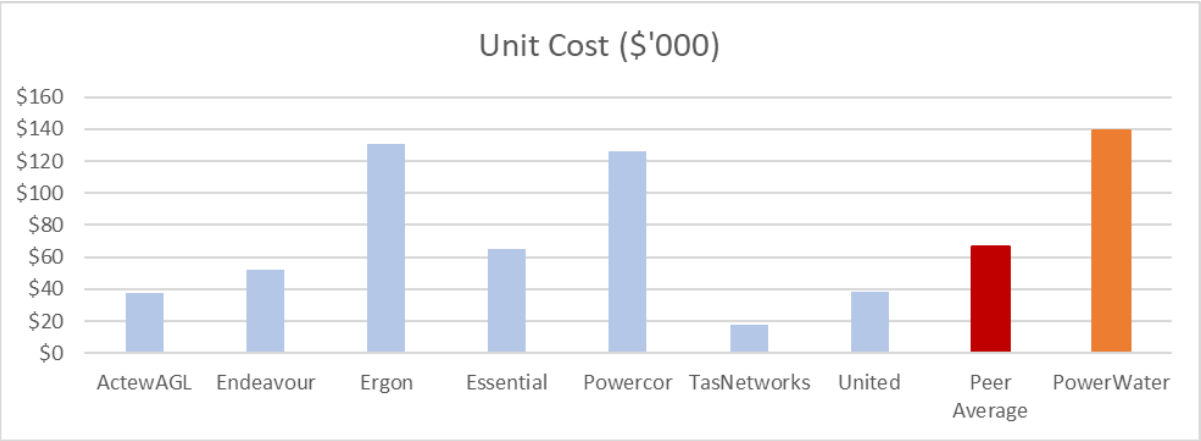
As part of the condition based distribution substation replacement program, one high fault level Magnefix substation is forecasted for replacement in the Darwin CBD in 2017/18 associated with the decommissioning of Austin Knuckey and West Bennet Switching Stations. Another two Magnefix substations (Darwin and Palmerston CBD) have been prioritised for replacement due to severe tank corrosion in 2018/19.

Validation

The cost estimate has been based on recent, 2015/16, replacement works undertaken. A benchmark of the cost against similar works undertaken by peer utilities indicates that the unit cost is reasonable. The comparison has been based on publicly available data sourced from the Australian Energy Regulator's (AER's) Repex modelling and utility Regulatory Information Notice (RIN) submissions. There are a number of internal and external operational, asset type, and environmental factors that influence the benchmark costs and provide a challenge in respect of the ability to undertake accurate comparisons. Normalisation for these factors has not been undertaken and the benchmark comparisons provided are an indicative measure of reasonableness only.

The compact nature of Magnefix switchgear allowed them to be installed in smaller distribution substation enclosures. Replacement with current standard distribution substations containing arc fault rated switchgear requires additional earthworks to install the larger footprint distribution substation, increasing the unit costs. In comparison with peer utilities the unit costs used for the forecast compares with the upper range of costs and is reflective of a unique network, unique climate conditions, and unique work environment.

Works undertaken in the Northern Territory are characterised by higher costs than other areas in Australia. This can partly be attributed to the remoteness of the network attracting additional transport and logistic costs, as well as the harsh weather conditions set apart by extended wet periods that impedes the effective execution of works and a tropical climate that impact on the productivity that can be achieved during normal work hours. Activity associated with cable installation is considered to require a High metabolic work rate, and is therefore heavily affected by the weather conditions in Darwin. Based on analysis conducted by Thermal Hyperformance[3], Workability for High metabolic activity reaches approximately 70% during only the coolest months of the year, June. In comparison, workability is not affected in any other major Australian centre except for during the hottest 2-3 months of summer.



[3] Labour Efficiency and Work Management in Hot Humid Climates, Thermal Hyperformance

Capex Profile

Phase (real $2017-18)*	2019-20 ($'000)	2020-21 ($'000)	2021-22 ($'000)	2022-23 ($'000)	2023-24 ($'000)	Total ($'000)
Investment Planning						
Project Development						
Project Commitment						
Project Delivery	1080	1063	876	827	797	4,643
Review						
Total	**1080**	**1063**	**876**	**827**	**797**	**4,643**

Variance

The forecast for this program of work extends beyond the current SCI period. The first two years of this program aligns with the last two years of the 2017-18 SCI.

Opex Implications

This program will have very little impact on Opex. As previously mentioned the failure rate of Magnefix switchgear within the network is increasing as the population approaches end-of-life. A number of strategies have already been implemented including detailed inspections of the switchgear terminals during planned outages for other works. In 2018/19 a program for intrusive maintenance and cleaning of the switchgear will also be introduced to stabilise both the functional and conditional failure rate. These programs will result in an increase in Opex associated with this asset class that will not be offset by the replacement volumes proposed.

Given the volume of installations of this type of switchgear, the program will target installations in residential and high pedestrian traffic areas initially to provide the most efficient public risk management. Units frequently operated will also be targeted to mitigate risk to high voltage operators due to the poor operator protection inherent in the switchgear design. Overall, the Magnefix switchgear assets have been highly reliable and low-cost but are now reaching the end of their useful life in view of their age, condition and operator protection limitations.