# AMS – Victorian Electricity Transmission Network

## Capacitor Banks

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| **Document number** | AMS 10-53 |
| **Issue number** | 9 |
| **Status** | Approved |
| **Approver** | John Dyer |
| **Date of approval** | 02/09/2015 |

# ISSUE/AMENDMENT STATUS

| Issue Number | Date | Description | Author | Approved by |
|---|---|---|---|---|
| 5 | 21/11/06 | Editorial review. | G. Lukies<br>D. Postlethwaite | G. Towns |
| 7 | 17/03/07 | Editorial review. | G. Lukies<br>D. Postlethwaite | G. Lukies |
| 8 | 12/12/12 | Editorial review. | D. Meade | D. Postlethwaite |
| 9 | 02/09/15 | Editorial review and addition of work order analysis. | T. Gowland<br>C. Odendaal | J. Dyer |
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# Table of Contents

# 1 Executive Summary

The Victorian electricity transmission network includes 71 capacitor banks in service at 29 terminal stations. Capacitor banks range in size from 5.4 MVAr to 220 MVAr and are connected at voltages ranging from 22 kV up to and including 330 kV.

The primary purpose of a capacitor bank is to stabilise the network operating voltage particularly during heavy demand periods. Capacitor banks can also minimise electrical power losses, optimise the utilisation of transformers and lines augmentations and act as harmonic filters in Static VAR Compensators.

Prior to 2003, many capacitor cans containing Polychlorinated Biphenyls (PCB) were replaced and thus the capacitor fleet is relatively young with a mean service age of 18 years. Consistent with the service age profile, the majority of capacitor banks are in very good and good condition, with zero assets in very poor condition.

Between 2003 and 2013, the volume of Defective Asset Reports (DARs) or system incidents for capacitor banks has exhibited year to year variation equating to approximately eight DARs annually. In 2014 there was an increase in DARs that caused the increase in capacitor bank issues operating at 66 kV and 220 kV.

Key strategies for the continuing management of capacitor banks are to:

- Continue to monitor the performance of capacitor banks.
- Continue to hold sufficient spares for capacitor cans to cover in service failures.
- Maintain adequate spares for capacitor bank reactors.
- Continue with the annual program of thermo-vision testing of capacitor banks.
- Implement the measurement and recording of individual capacitor can capacitance measurements together with their serial numbers and unique location.
- Continue to monitor the reactors with paint flaking off for any rapid deterioration.

# 2 Asset Summary

AusNet Services' transmission network contains approximately 11,500 capacitor cans equating to 6,000 MVAr of capacitance. These are arranged in 71 Shunt Capacitor banks at 29 terminal stations within the Victorian electricity transmission network to:

- Reduce the risk of transmission system voltage collapse during heavy demand periods.
- Minimise transmission system power losses.
- Defer transformer and line augmentations.
- Filter harmonics from SVCs.

Capacitor banks range in size from 5.4 MVAr to 220 MVAr and are connected at voltages ranging from 22 kV up to and including 330 kV. These banks perform a vital voltage support function that is critical at high network loads. Each capacitor bank includes detuning reactors to limit inrush currents and capacitor cans to store and deliver reactive electrical energy.

ABB is the predominant manufacturer of the 20 different types of capacitor cans installed on the network. In Figure 1, the fleet is expressed respective to capacitor bank rating and respective operating voltage.

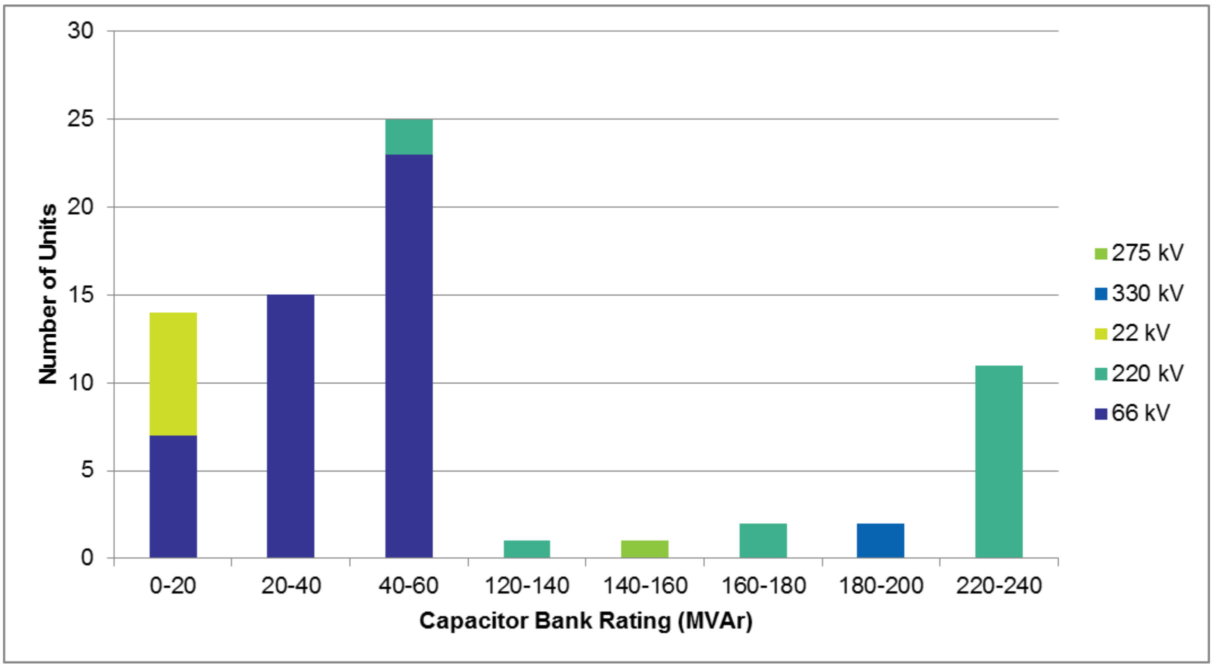


Figure 1 – Capacitor Banks by Voltage

Most capacitor banks are switched by reactive-demand or time-based controllers to provide necessary reactive compensation at times of peak loading. With the high utilisation of transmission network assets over the last decade, the number of switching operations, duration of capacitor bank operating periods and duty has been significant.

Construction of the fourth 500kV Cranbourne terminal station transmission line and generation projects in the western side of the state at Mortlake Power Station (MOPS) and Tarrone Terminal Station (TRTS) has resulted in a softening of overall capacitor bank utilisation compared to 2007.

# 3 Age Profile

Prior to 2003, many capacitor cans containing Polychlorinated Biphenyls (PCB) were replaced and thus the capacitor fleet is relatively young with a mean service age of 18 years. As represented in Figure 2, approximately three quarters of the capacitor banks have been in service for less than 20 years. The small population which have exceeded 30 years in service are now approaching the end of their expected service life. The expected service life of a capacitor is about 40 years but this is foreshortened by high utilisation rates. Figure 2 expresses the fleet respective to capacitor bank age and respective operating voltage

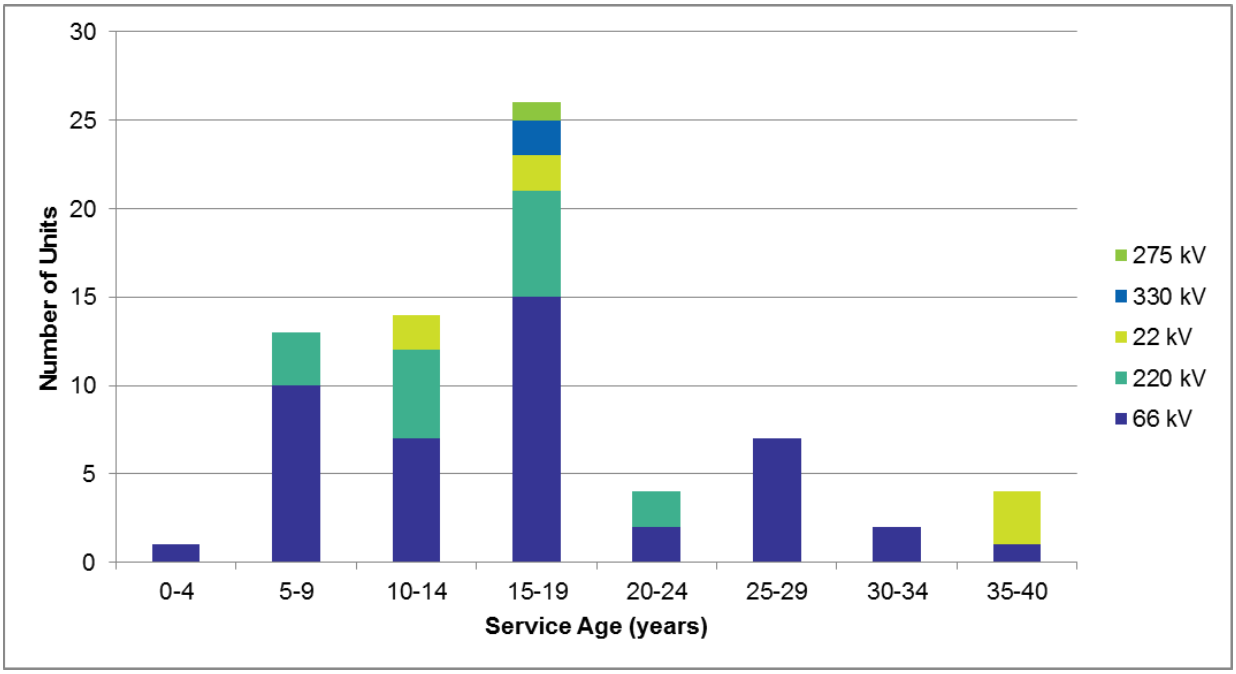


Figure 2 – Capacitor Banks by Age

# 4 Condition Summary

The condition of the fleet has been assessed using a consistent condition methodology that uses the known condition details of each asset and grades that asset against the common asset condition criteria. The overall condition is determined by weighting individual component condition assessments for each capacitor bank.

Table 1 provides the assessment of the condition scoring for the fleet. The condition of each capacitor bank has been scored ranging from condition C1 (very good) to condition C5 (very poor) accordingly by applying the criteria.

| Condition Scorecard | | | |
|---|---|---|---|
| **Condition Score** | **Condition Description** | **Summary of details of condition score** | **Remaining Service Potential** |
| C1 | Very good | These Capacitor banks are generally less than 10 years old and in good operating condition with no past history of defects or failures. Manufacturer support and spares are readily available for routine maintenance. Routine maintenance and continued condition monitoring is recommended. | 95% |
| C2 | Good | This category includes capacitor banks which are in better than average condition for its service age and technology type. They may not have developed actual faults but developing minor issues due to connection, secondary or other unknown causes. They do not require intervention between scheduled maintenance nor do they show any trends of serious deterioration in condition or performance. Manufacturer support and spares are available. | 70% |
| C3 | Average | This category includes capacitor banks which are with an average condition for its respective service age and technology type. (Some cap banks may have capacitor cans, reactors replaced and by doing so condition had improved to average level). These units particularly require increased maintenance. Spare reactors and cans are being used to replace cracked reactors and defective cans. Air core reactors have paint peeling off. | 45% |
| C4 | Poor | This category includes externally fused old capacitor cans which are in worse than average condition. They may have developed an increasing number of defects due to frequent fuse blowing, unbalance protection trips and other secondary issues which require frequent intervention. In situ repair are becoming the most practical and keeping a higher level of spares is required. | 25% |
| C5 | Very Poor | This category includes capacitor banks which are typically maintenance intensive and have history of failures of cans, reactors and CT's. Frequent unbalance alarms occur and the consumption rate of cans is unacceptably high. These cap banks are approaching the end of economic life. The defects develop within the maintenance inspections and lack of availability of spare parts is a major concern. The maintenance of capacitor bank is typically becoming uneconomical compared to asset replacement. | 10% |

Table 1 – Capacitor Bank Condition Scorecard[1]

The majority of capacitor banks are in very good and good condition, with zero assets in very poor condition as illustrated in Figure 3. For further detailed information regarding the condition assessment framework, specific issues, conditional maintenance activities and discussions of failures, refer to AHR 10-53, Capacitor Bank Asset Health Report.

[1] AHR 10-53 Capacitor Banks.

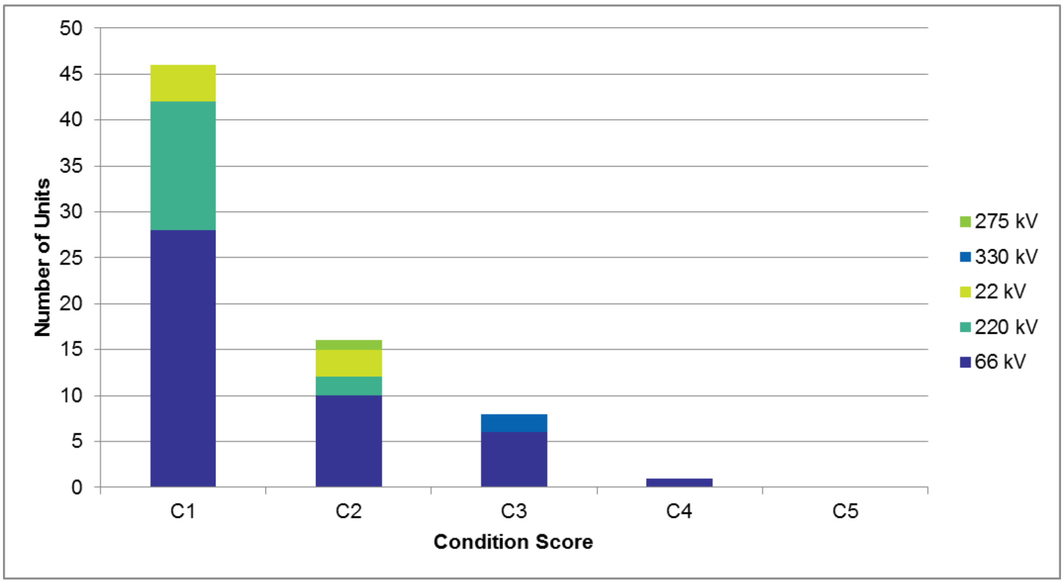


Figure 3 – Capacitor Bank Condition

Due to the configuration of capacitor banks, individual capacitor can measurements were dependant on disconnecting each can. Instrumentation is now available for measurement of individual capacitor can capacitance and dissipation factor while connected in a series or parallel group. These records can be uniquely correlated to each individual can by location and serial number. When capacitor cans are replaced, the records in the asset information system will reflect the associating characteristics and test results.

## 4.1 System Incidents

System incidents and defective apparatus are reported against an individual asset. Analysis of directly attributed System Incident Reports (SIRs) and Defective Apparatus Reports (DARS) for capacitor bank unbalance trips and alarms have been evaluated and shown in Figure 4.

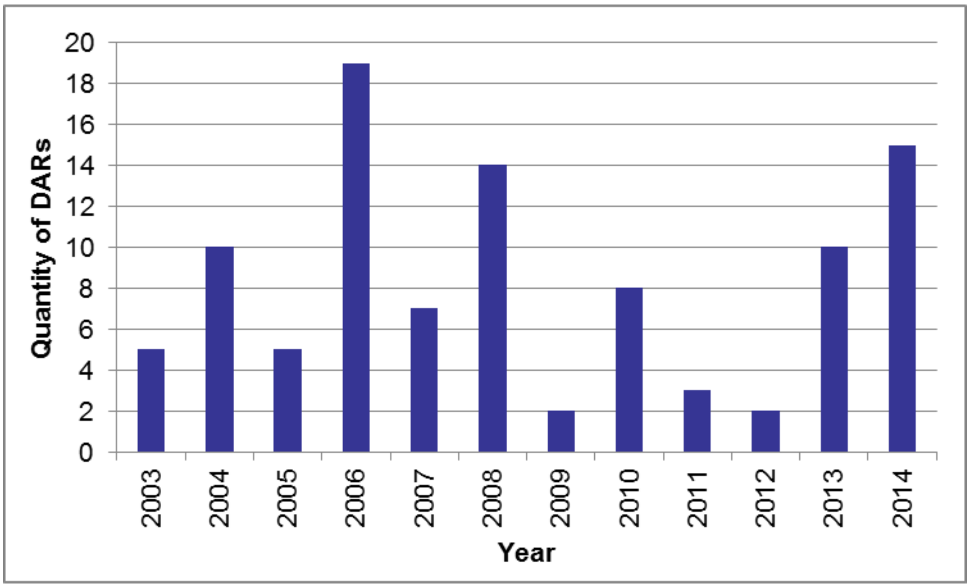


Figure 4 – Capacitor Bank population Defective Apparatus Reports (2003-2012)

Between 2003 and 2014, the volume of DARs for capacitor banks has exhibited year to year variation equating to approximately eight DARs annually. In 2014 there was an increase in DARs that caused the increase in capacitor bank issues operating at 66 kV and 220 kV.

# 5 Key Issues

Due largely to the relatively young service age and good condition, in recent years work on capacitor banks has been largely of a scheduled nature and with only a modest amount of in-service failure of a small number capacitor cans (units) as they deteriorate with service utilisation and voltage surges.

Capacitor can failures causes out-of-balance alarms or, in some cases, tripping of the capacitor bank. In either event, measurements of all can capacitances and rebalancing is required. The repair of faulted capacitor cans is not economically viable; they are replaced with spare units on failure. Prior to the event, it is difficult to detect or prevent these failures without substantial investment (in routine capacitance testing for example) or by over design of the capacitor units. The trend of can failures is monitored for each cap bank and when the trend continues to deteriorate to a point where wholesale replacement is more economic.

Corrective work is sometimes needed due to flashovers caused by birds or small animals, or hot joints developing on inter-plant and inter-can connections. The mass of modern capacitor cans is too great for manual handling and so they have to be moved with the use of cranes or specifically designed davits. Handling of cans still does pose OHS issues for Field staff and the safety in design aspects of new Capacitor Banks requires review.

When analysing the work orders associated to the fleet, Out of Balance and Connection issues were the main contributors, as shown in Figure 5.

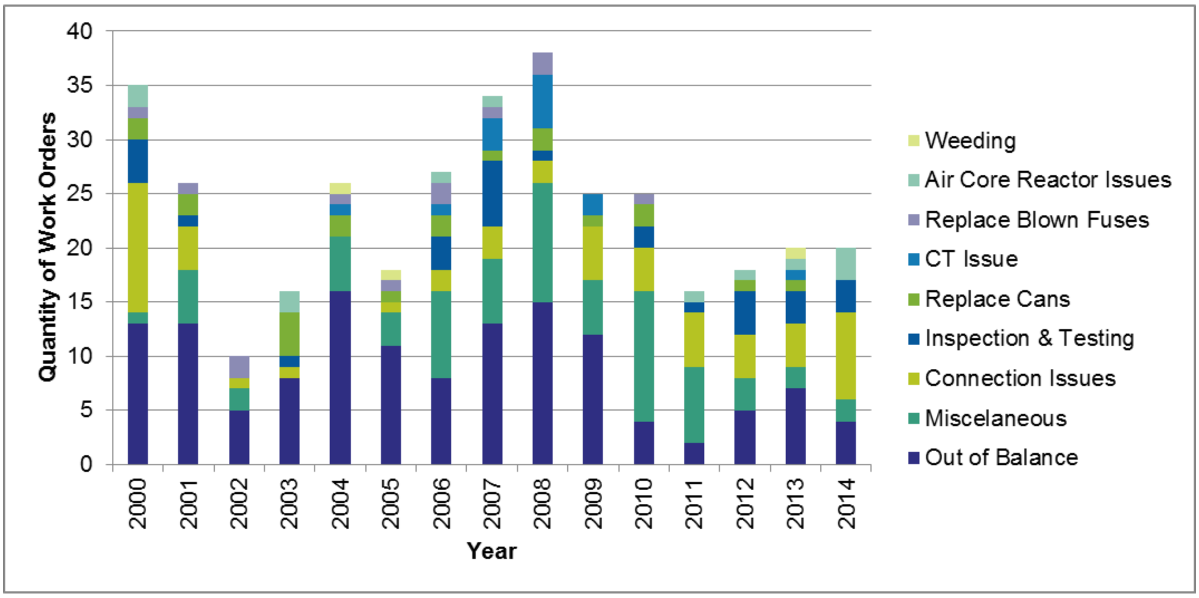


Figure 5 – Capacitor Bank Work Orders

The failure of several air cored reactors on 66 kV capacitor banks in a short time triggered a detailed investigation and a subsequent increase in spares held. The failures have not continued. On a number of air core reactors, the exterior paint has peeled off, which has not directly led to failures, but are being monitored for any rapid deterioration as the paint protects the fibreglass from moisture and contaminant ingress.

# 6 Strategies

Key strategies for the continuing management of capacitor banks are to:

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