Picking up the pieces

… the rebuilding of Ballarat Tramway Museum's traction power supply following its destruction in 2004.

Introduction

This paper outlines the events leading to the total power supply failure and the 12 month process that followed. While some obvious technical details are covered, particular emphasis is paid to both the organisational challenges presented and the impact on the volunteer workforce which the museum relies so heavily upon for its existence.

The joint authors are Garry Wood and Paul Mong, both of whom are long time members of the Ballarat Tramway Museum. Garry is currently Technical Services Manager and holds qualifications in the field of electronics while Paul is involved in tram restoration and maintenance and is a trade qualified electrician with extensive experience in industrial control systems.

As is no doubt widely known by now, a lightning strike on the 13th of October 2004 followed by a small fire on the 19th of October in the switching equipment for the traction substation resulted in the complete disconnection of the AC mains supply to the BTM tram depot. This set in motion a series of events which will likely be remembered as a turning point in the history of the museum and have become a catalyst for ongoing changes and improvements to all aspects of the museum's operation and future planning.

The morning after

While the actual day of the fire came and went with much effort expended on cleaning up the aftermath and phone conversations continued until late into the evening, it was not until the morning after when we arrived at the depot to inspect the actual electrical equipment and assess the process of repair that the reality of what had happened began to become clear. Two things were more evident than anything else at this point, the BTM was now unable to carry on its function of operating a vintage tram service and consequently would be deprived of its main source of income until services could be resumed, and a fire had burned unchecked within the main traction switch for more than 12 hours while the depot was unattended.

With regard to the lack of income we were confident that the museum would be able to survive for a short time by using its carefully managed cash reserves. However the fact that a fire, contained only by a small metal box and a perspex sheet, had gone unnoticed and unchecked for the entire night of October 18th and could so easily have spelled the end of all that we had worked for over the past 30 years was, almost unknowingly, to play a significant role in the decisions that were to be made in the weeks and months ahead.

Optimism galore

I don't know whether it is just the nature of certain people or if it comes with the mindset of being a volunteer, but we proceeded with an optimism that we could get things back into operation within a couple of weeks in spite of everything that had occurred. New switching equipment was sourced and ordered, electrical contractors were scheduled and plans were put in place to carry out the necessary work to repair the damage. Plans were even made to make some improvements to the overall electrical installation and thereby bring the museum a little closer to living in the 21st century and the standards that prevail today.

The fact the original designer of the equipment could not be contacted, having chosen this particular time to embark on a round Australia holiday, and that no diagrams or specifications were able to be located was not even enough to dent our optimism. Perhaps in the end this lack of information from the past was to become a blessing as it necessitated a lot of rethinking and evaluation of our actual needs.

The end of the line

When we focused our attention on the isolating transformer and found that the primary winding had gone very low resistance to ground we, with our continuing optimism, set about arranging to have it repaired. After several phone calls, an aborted attempt to open the case and a visit by a local motor winder, who was slightly taken aback when he saw the size of our “small” transformer, we duly delivered it to ABB in Melbourne and waited for their verdict. Right about now we began to appreciate the difficulties that apply to dealing with antique electrical equipment. As we waited an agonising 10 days for a PCB test on the transformer oil, we read with some degree of horror the EPA regulations relating to PCB transport, storage and decontamination and began to picture us being overrun by men in Hazmat suits with clipboards and stern faces. Fortunately the oil was free of dangerous PCBs, but unfortunately the oil contained a high quantity of water which had badly damaged the internals of the transformer, a one way trip to the scrap yard for our 1932 antique and we were left with the lingering question of what now?

Starting over

So now we are not really repairing a damaged traction power supply, we actually seem to be building a new one. It was not until this realisation hit us that things really started to get moving in a positive direction. Of course there was a small matter of sourcing a new transformer but even there we discovered that for a price that was actually well within our reach we could have a brand new one manufactured to our specification and delivered in a month or two. In fact the design required to operate our tramway is so commonly used in industrial, medical and computer installations today that we obtained no less than 5 separate quotes for a replacement.

Having spoken almost daily for the past couple of weeks and discussed at length the details of what needed to be done, it seemed that both of us had changed our mindset from repair to replace at about the same time and began to think of the task in a much more professional way. On looking at what was left from the original power supply it seemed quite obvious that there really wasn’t any point in keeping anything, why not just replace the lot with a new design and new, or less antique, components.

Past, present and future

Yes there were some comments from others such as “aren’t we meant to be preserving the past”, but the museum had to consider its future survival in a world that has changed enormously in the past 30 years. We came to the conclusion that infrastructure, like the power supply, was just infrastructure and was not the fundamental thing we were preserving. While this view is not universally shared, even within the museum board, it is the sort of reality that must be faced in order to continue to do what we do.

Consider this, if at some time in the future due to some unforseen world events, the only way to operate our trams was using aluminium rails with carbon fibre sleepers, would we do so even though it is not the historically correct infrastructure? Ultimately this is the balancing act that must be weighed up when we think of preserving the past versus surviving the future.

A little more

After a triumphant return to service, you could be forgiven for thinking that all was well and everything could return to normal. But after so much work the two of us didn’t feel that was quite it, so after some lengthy discussions with various members, much more research and a unanimous vote by the board, out came the remaining “less antique” equipment and in went brand new circuit breakers and electronic overload detection equipment along with new feeder cables and negative returns.

Now finally things were up to scratch and we could confidently say that this piece of infrastructure will last us well into the future. The trick now is for someone to know when it comes time for replacement again.

Lessons learned

If you ever find yourself in a situation where your organisations survival depends on your ability to overcome a major obstacle, here are a few small things we learned along the way. Some of them may be helpful to you:

1. Work on big tasks with a person who you trust, you won't agree on everything but you will stop each other from making many mistakes.
2. Get to know suppliers in your industry, they are professionals and can find products for you that you would never know existed.
3. Communicate continuously. Phone calls, emails, newsletters etc. Make sure everyone knows as much as you can tell them, telling them more than they care to know is still better than leaving them in the dark.
4. Accept all offers of help, you really don't know what you are going to need when you start out on a major project and occasionally people come up with exactly what you want without even knowing.
5. Keep your focus, don't become sidetracked or disheartened if there are setbacks. Your focus will keep those around you motivated to achieve the goal even if the end seems a long way off.

And some forgotten?

And a couple that could easily be forgotten over time as the day to day routine returns to normal:

1. Remember what's important to your organisation, sometimes secondary interests can become more prominent than they really should be. For the BTM this means preserving and protecting our unique tram fleet, their history and their story, everything else is secondary.
2. Take stock of where you are now and take action before you really need to. Remember that we are preserving the past not living in it and planning now is much better than picking up the pieces later.

Technical Details

Overview

The final design of the new power supply is a fairly conventional 3 phase transformer with 6 pulse rectifier and overload detection equipment. The basic components of the system are:

- Main switch
- AC contactors
- Transformer
- Diode rectifier
- DC breakers
- Overload and fuse protection
- Control circuitry

Transformer

The transformer was manufactured in Australia and is from a standard range designed for power isolation and clean power systems. The specifications of the transformer are:

- 3 phase 415V AC standard isolation transformer
- Rated at 200KVA
- Primary winding configuration - Delta
- Secondary winding configuration - Star
- Air cooled in IP21 enclosure

The choice of an air cooled transformer was necessitated by several factors including the regulations surrounding the use of oil cooled transformers inside buildings, the risks of oil fires and explosions and the higher ongoing maintenance costs of oil filled units.

Rectification

The rectifier is a standard 3 phase 6 pulse design utilising 6 diodes rated at 240 amps each.

DC line breakers

The DC line breakers fitted to the new power supply (one for each feeder) are a Spanish unit manufactured specifically for traction installations. They have the following features:

- 400A main contacts
- 230V DC control coils
- DC breaking capacity of 1600 amps at 15 milliseconds
- Making capacity of 10,000 amps
- Magnetic blow out coils for arc suppression
- Multiple auxiliary contacts for control circuitry

The DC breakers were chosen because they offered significant benefits over other possible designs including:

- Ability to isolate individual feeders using modern lock-out tag-out safety standards
- Ease of control using standard components
- Ability to use an electronic device for overload detection
- Speed of breaking and low arc emission at high currents
- Physical dimensions and weight (only 13Kg per breaker)
- Low cost per unit and easy access to spare parts (approximately $3000 per unit)

Overload and fuse protection

The overload detection devices chosen to monitor current in the DC breakers are an Italian designed unit that is available in a range of models to suit the particular design needs. The main features of these units are:

- Electronic overload detection using a 0-60mV signal from a shunt
- Reaction time of 100 milliseconds
- Adjustable overload set point and adjustable delay
- Simple control and reset circuitry
- Low cost (approximately $300 per unit)

To provide second level protection to all major components in the power supply the following fuses are used.

- 3 x 200A AC fuses on output of main switch
- 3 x 315A AC fuses on secondary winding of transformer
- 1 x 600A DC quick acting semiconductor fuse on output of rectifier

In normal operation the overload detection devices and line breakers will react to any overload and short circuit conditions, the fuses are designed to protect the equipment in the event of an abnormal event or component failure.

Control circuitry

All control circuitry is low voltage (230V AC) to allow use of standard components such as switches, relays, meters and indicator lamps. The use of low voltage control equipment also allows fully remote operation in normal use with no staff required to enter the switch room at any stage, thereby avoiding any potential for contact with high voltage equipment.