Power system simulation studies

in the growth of Northparkes Mines

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***Abstract* — This paper presents several case studies of how mine expansion can be carefully planned and managed with respect to the power system. Power system studies become more important as the site approaches operating load limits within its existing infrastructure. Developing an accurate power system model for simulation studies not only aids in keeping the site safely operating, but also reduces costs by maximising existing infrastructure and supporting investment plans with confidence.**

***Index Terms* — Power system, modelling, simulation, load flow, short-circuit, protection coordination, arc flash hazard assessment, power factor correction, cost benefit assessment, DIgSILENT PowerFactory.**

I. INTRODUCTION

Electrical power system simulation begins with the model of the power system under study where simulations are executed to analyse the behaviour of the electrical power system. Power system simulation is used across generation, transmission, distribution, industrial, mining, railway and commercial facilities. Common uses of simulation for power systems include load flow, short-circuit or fault analysis, transient or dynamic stability, harmonic or power quality analysis and optimal power flow.

In the mining industry, power system simulation is used for planning, such as in the investigation of plant expansions and development options, transformer, overhead line and cable sizing, switchboard rating, power factor correction and the cost benefit assessment of investments.

In operating the mine, simulation of power systems aids in protection coordination of relays, arc flash hazard management and optimisation of the network to reduce voltage drop and losses. Furthermore, dynamic analysis such as motor starting of large mills, fluctuating loads (e.g. winder) and power quality concerns (e.g. harmonics, flicker) can be examined in a power system simulation platform.

II. NORTHPARKES MINES POWER SYSTEM MODEL

Northparkes Mines (NPM) is a copper-gold mine owner-operator located in the northwest of Parkes in central NSW. DIgSILENT Pacific (DIgSILENT) has in the last 10 years conducted power system studies for NPM in load flow, short-circuit, protection, arc flash and harmonic studies. NPM has produced high grade copper-gold concentrate since 1994 and is presently in a phase of rapid expansion.

The initial power system simulation study for NPM was developed to quantify the arc flash hazard of their existing site. To perform these calculations, the NPM power system was modelled in the PowerFactory power system software. This includes the electrical infrastructure from the 132 kV point of connection, the main incoming transformer switchyard, 11 kV main substation and feeders, to the LV distribution boards supplying 1000 V and 415 V loads.

III. ARC FLASH HAZARD ASSESSMENT

Arc flash hazard assessment is a key safety initiative intended to reduce the risks for staff operating or working in proximity to switchgear. The assessment requires modelling of the relevant network and calculating the incident energy that may accompany an arcing fault.

Data collection for arc flash hazard assessment includes inspecting switchboards and capturing all protection relay settings for calculation of fault clearing time and grading assessment. A sufficiently detailed model in PowerFactory allows determination of actual tripping time for each protective device to calculate incident energy up to two seconds, which is a reasonable maximum time for calculations as per IEEE 1584 [1].

In reality, the electrical worker undertakes a wide variety of tasks and they vary in risk in terms of the likelihood of causing an arcing fault. Additionally, dependant on the task, the electrical worker has varying levels of exposure to an arc hazard. Once this is recognised, the components of risk analysis become obvious and the various work activities can be individually addressed in terms of the appropriate Personnel Protection Equipment (PPE) countermeasures [2]. Hence, a database stores the assessment data and applies the business rules for each assessable location with respect to activity as shown in a sample arc flash label in Fig. 1.

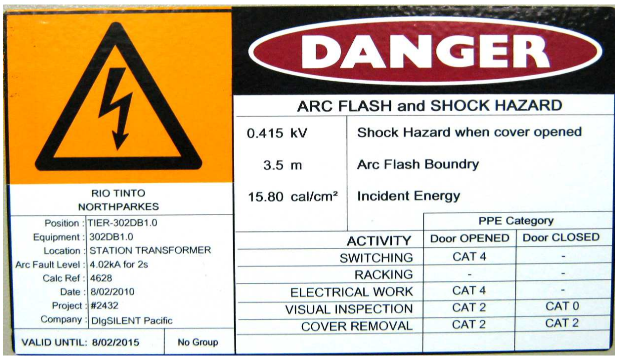

Fig. 1 Arc flash label sample

IV. Protection Coordination

The complete power system model is the base from which further studies are built. For instance, in the course of upgrading the main substation 11 kV protection relays, protection curves were graded against the existing upstream and downstream protection device models to assess coordination and determine their settings for commissioning as demonstrated in Fig. 2.

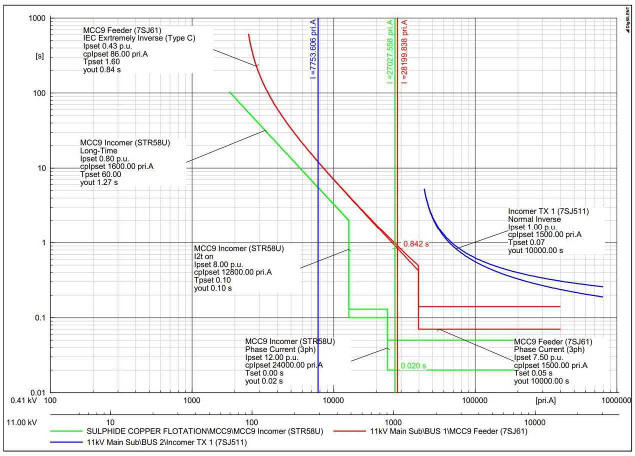

Fig. 2 Protection coordination of upgraded relay

As the 11 kV relays were upgraded in phases, DIgSILENT managed the NPM protection device types and settings lifecycle stages from planning, pending, applied and historic in an asset management system. As a result, protection studies can be performed with confidence on the concurrence of the protection settings in the model with that commissioned on site.

V. Mine Expansion

As the mine expands, the impact of additional load and network modifications can be assessed using the power system model. Connection possibilities and their impact to the electrical system are assessed to determine the best option. The assessment of the proposed new loads includes their impact on increased loading on existing equipment such as transformers and cables.

In order to establish the existing base load reference of the NPM site, the PowerFactory model loads were aligned with the average and maximum readings of the 11 kV main substation during the record production month. The existing load flow uncovered several substations that could potentially operate outside the voltage steady-state limits under some conditions as shown in Fig. 3. DIgSILENT recommended that the respective transformer taps be changed to the proposed positions in order to restore the busbar voltages to within steady-state limits, thus restoring operation closer to nominal voltage under average load as presented in Fig. 4.

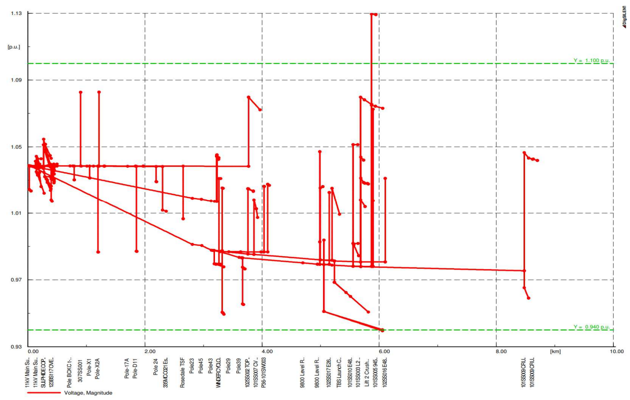

Fig. 3 Existing average loading with existing taps

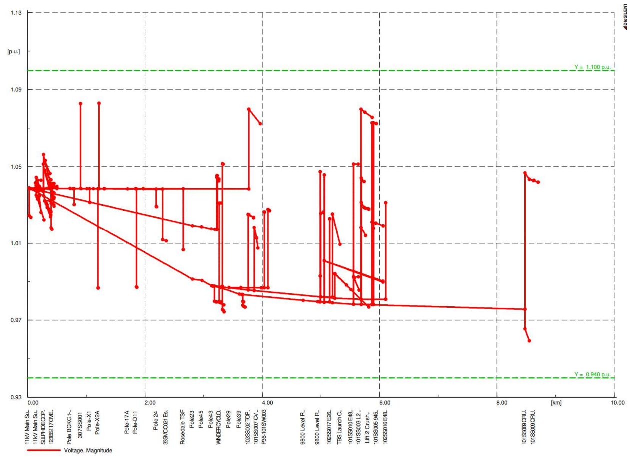

Fig. 4 Existing average loading with proposed taps

Subsequently, additional loads from the proposed expansion projects were modelled. The repeated load flow study of average loading in Fig. 5 demonstrates that the substation voltages on site are expected to remain within the acceptable range of –6% to +10% of nominal. However, when maximum current is considered, potential under-voltage excursions were identified on coincidence of peak loads as presented in Fig. 6. Nonetheless, this is a low probability due to diversity of load on site.

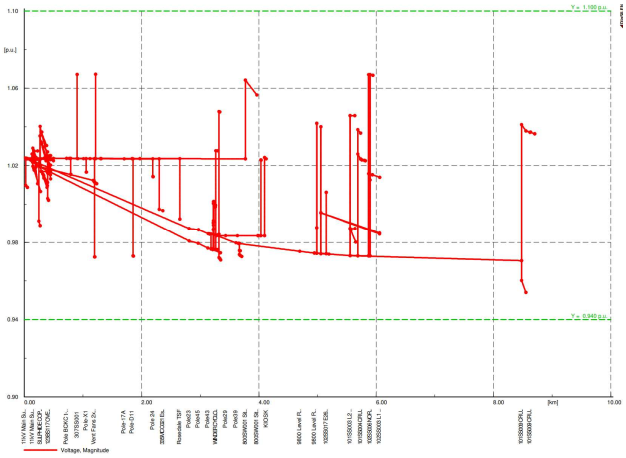

Fig. 5 Average loading with additional load

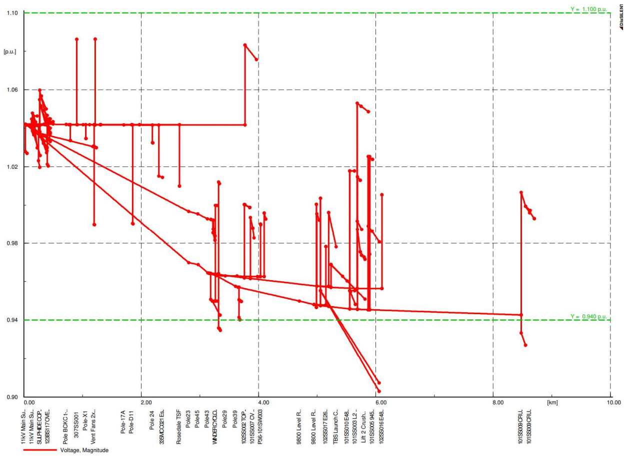

Fig. 6 Maximum loading with additional load

VI. Trip of Power Factor Correction

Normal operation of the site is with the power factor correction (PFC) facility in service to achieve a suitable power factor of 0.96 at the 11 kV main substation.

To analyse the effect on voltages in case the PFC trips, two consecutive load flows are conducted; one with and another without the PFC in service. The difference in voltages are reported, prior to the main incoming transformer on-load tap-changer (OLTC) tapping.

Based on these consecutive load flows simulated, a trip of the PFC would cause a 4% drop in voltage to 0.99 pu at the 11 kV main substation. Loads connected further from the 11 kV main substation would observe more than 4% reduction in voltage due to the additional voltage drop along the lines. Potentially, underground substation loads towards the end of the supply line may trip on under voltage upon disconnection of the PFC. However, this is an unlikely scenario as a PFC trip is a rare occurrence. Nevertheless, the information is helpful to allow planning and safety arrangements for the case where the event does occur.

VII. Power Factor Improvement

Improving the power factor of the site is achieved by locally delivering the necessary reactive power so that the value of the current and consequently of the apparent power supplied from the upstream network can be reduced.

Upon modelling additional loads from the proposed expansion plan, simulation reveals that the site power factor is reduced from the existing 0.96 to 0.93. Hence, a cost benefit assessment is conducted by way of simulation.

The main benefits of improved power factor are loss reduction and the ability to supply increased loads with existing transformers. By way of simulation, DIgSILENT considered an additional 5 Mvar bank, which improves power factor from 0.93 to 0.97. Reduced transformer losses of 22 kW over 8,760 hours a year at a nominal $100 per MWh would result in a savings of $19,000 annually. However, given the capital cost required to achieve this improvement likely exceeds the expected savings, economic justification to improve the power factor of the site may not be supported solely by reduced transformer active power losses.

In addition, as a consequence of the improved power factor, an additional capacity of 2 MVA is available to supply increased load on site with the existing transformer. This allows for potential deferred capital investment and economic benefits through increased production, which may support the proposition for improving the power factor on site.

VIII. Conclusion

The case studies in this paper illustrate how power system analysis answered questions in the investment of new plant, improving operational reliability and in planning expansion of the mine site. These outcomes underline the advantages of managing a mine power system from design through to operation using power system simulation tools. Therefore, power system simulation studies using a detailed model of the plant aids in managing and expanding a site with confidence while saving costs and keeping the site safe.

References

[1] IEEE Guide for Performing Arc-Flash Hazard Calculations. 2002. IEEE 1584

[2] P. Willis, Arc Flash Standards - Australian Developments, Electrical Arc Flash Forum 2010