KD01 CONVEYOR - KYUGA COAL
ANGLO-AMERICAN, HUNTER VALLEY, AUSTRALIA

PETER R. GILBERT
NEPEAN CONVEYORS INTERNATIONAL PTY. LTD

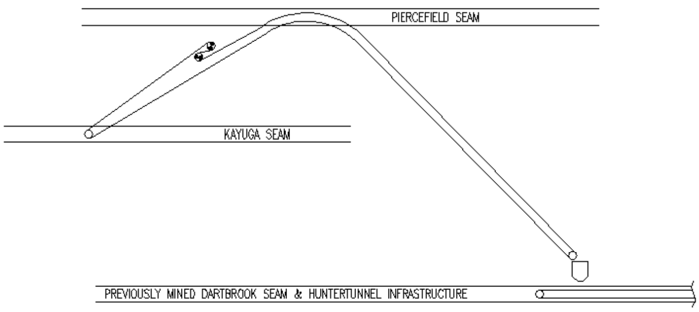
INTRODUCTION

The Kyuga Three-Seam "Hump-Back" Decline Conveyor Project was designed between The engineering department principals of Nepean Conveyors and Kyuga Coal, where Anglo-American (Owners of Kyuga Coal) owned a large investment in tunneling and pre-existing Trunk Conveyor Infrastructure in the Dartbrook Seam that due to poor geological mining experiences, had been Under-utilized at the time the Dartbrook seam operations would cease.

The Coal Seam above Dartbrook (Kyuga) and the coal seam above Kyuga (Piercefield) Were next prospects to be mined, each requiring in normal procedural circumstances, considerable expense and time to drive and install a further set of Trunk Conveyor driveage & infrastructure prior to mining activities could resume for the Kyuga and then the Piercefield prospect.

As with all new coal mine prospects, the capital infrastructure is weighed off against the return on investment and, methods were sought to reduce the capital investment for the Kyuga and Piercefield opportunities as the likelihood of successfully mining them would depend on reduction of capital & greatest utilization of existing infrastructure.

Kyuga project management proposed a “Three-Seam Hump-Back Conveyor” (See Sketch # 1) which would carry the Mined coal from the new Kyuga seam up to the Piercefield Seam and then down to the Dartbrook seam via a storage bunker thus utilizing the existing enormously valuable and existing “Hunter Tunnel” drivage, conveyors & infrastructure for the extraction of the entire Kyuga seam. The features of the VVVF conveyor system Nepean Conveyors proposed, allowed following mining the Kyuga seam, to shorten the “Hump back” conveyor from tail end towards delivery point thus positioning the new “Load” point in the Piercefield seam further above the Kyuga seam such that the same conveyor and existing infrastructure & drivage would be utilized along with the Dartbrook Hunter Tunnel infrastructure to realize its fullest utilization in extracting the Piercefield seam.



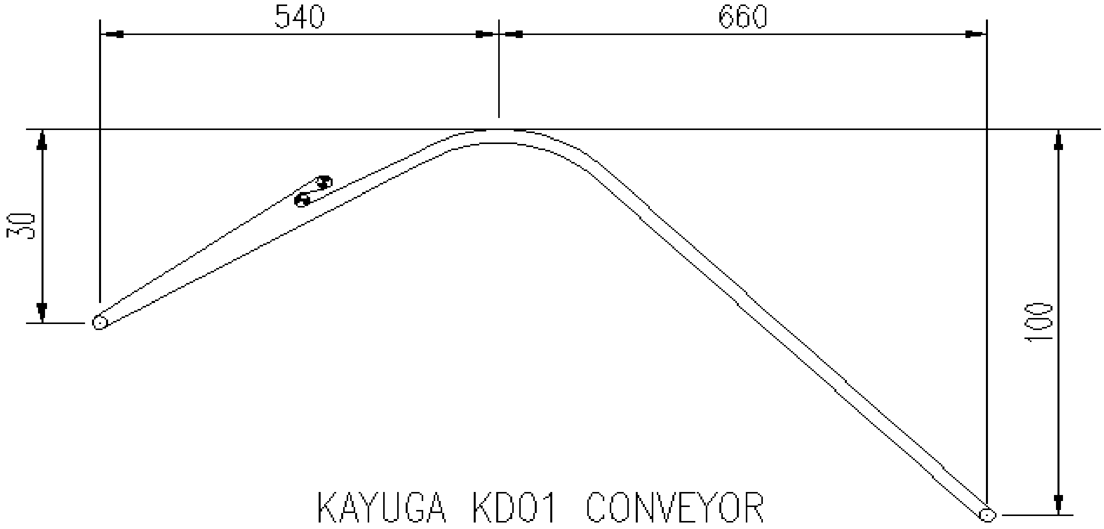
Sketch # 1…Three seam KD01 Decline Conveyor

THE TECHNICAL CHALLENGES.

The KD01 decline conveyor was to be built and operated in Kyuga Coals underground coal mine in the Hunter Valley, NSW, and Australia.

In doing so, it would be subject to the stringent design & regulatory criteria implied by the Mines Department of NSW for equipment operating in a gassy environment, class 2, zone 2.

Conceptual design of the conveyor (Sketch # 2) evolved somewhat likened to an inverted "Boomerang" with one leg longer than the other, that being the decline component of the conveyor.



Sketch # 2

Further calculations concluded that were the conveyor to be loaded in the "uphill only" a power demand of 650kW would be required of the drive system, however, were the conveyor to be loaded in the decline portion only, the conveyor system would regenerate some 800kW of power.

It would follow, if the conveyor were fully & continuously loaded at its design capacity of 4,200 t/p/hr, (as all Mine Managers dream of) the conveyor would continuously regenerate 150kW of power that would need to be dealt with.

Were the conveyor to be loaded in the decline portion only at a time when the conveyor is required to stop, a peak power of 900kW would be required to stop the conveyor in 60 seconds however, were the conveyor to be stopped loaded only in the incline, the conveyor would stop itself naturally in eight seconds.

NSW mine regulations dictate (quite sensibly) that in the case of regeneration, where a brake method is used, should it fail, a second means of braking must be available to the system, which in turn suggested, 1800kW of braking power should be available in two stages somewhere in the conveyor system.

A further requirement by Anglo-American was that no battery back up was acceptable in the mine. I.E.: Were the power to drop out entirely, thus stopping the ventilation fans, no battery back-up would be allowed given stringent ruling under lack of ventilation.

So, in summary:

The conveyor must be capable of driving & controlling powers from positive 650kW to minus 800kW and back in swings within five minutes, have the capability to stop with 900kW of braking power in a gassy coal mine, with no mains power and then decide at the appropriate time after the lights have gone out, that its first 900kW of braking power has died in action, then find a second 900kW of braking power to stop the conveyor in a controlled manner but no longer than sixty seconds.

Bear in mind, this conveyor is the "life blood artery" for the entire Kyuga and Piercefield seams for which a healthy fifteen years of life is expected.

THE OPTIONS OF DRIVE TECHNOLOGY AVAILABLE.

The KD 01 conveyor would re-generate considerable power under decline loaded-only conditions and require considerable power to drive the conveyor in the case of incline-loaded only.

In the fully loaded condition, the conveyor would continuously re-generate 150kW.

It was deemed that the continuously re-generated power would be filtered then supplied back to the grid rather than provide on-site heat sinks or various other methods such as converting the energy to heat prior to dissipating to air.

A further requirement was the ability to provide a controlled and lengthy start to the conveyor along with a gentle 60-second "power-down".

The most modern technologies available to reliably perform all of these functions were the Viscus Friction Clutch (VFC) and Variable Voltage Variable Frequency (VVVF).

Given the VFC technology separates the drive pulley from the electric motor via a releasing "clutch", it was, in comparison to the VVVF technology, considerably more complicated and introduced further risk.

Further, a comparison risk review on the two technologies highlighted the additional control code; logic & components required in the VFC to ensure that the electric motor remained connected to the drive pulley under any condition.

This led to the choice of VVVF as the preferred drive technology.

Further comfort to the VVVF choice lay with the fact that Nepean had, two years earlier, designed, manufactured and successfully installed a "Four Quadrant", continuously regenerating VVVF decline conveyor underground at Southland Mine's NE1, albeit, with an installed lower power of 330kW.

Although the NE1 conveyor was one-third the power installed, the same complexities applied to the ramping, power-down, emergency-braking processes in an underground coal mines gassy environment.

THE VVVF TECHNOLOGY.

At this point and for those that are not aware, I should provide a layman's explanation of how the VVVF power & control system works

Essentially, Variable Voltage Variable Frequency (VVVF) technology is provided via two items:

- The VVVF alternating current electric motor.
- The VVVF drive stage.

1….The A.C. motor is not unlike any other electric motor however, it is fitted with a secondary fan and fan motor of around 4kW to provide air-rush cooling over the main motor when it is working hard & producing a lot of heat but revolving quite slowly, for example, at the start of an acceleration to full speed.

The VVVF motor also carries specially insulated bearings to ensure no static arcing occurs across the outer motor winding to the stator thus damaging the bearing roller surface.

2… The key to VVVF control is the drive stage. Essentially, it's a box of electronics with replaceable cards (two units about the size of a suitcase would drive a 500kW motor) that converts the A.C. current to D.C. current, "chops" and appropriates the required motor voltage & frequency, then converts back to A.C. current prior to charging the A.C. motor with the desired "flux" to rotate the motor at the speed and torque required.

The net result is, by varying the voltage & frequency of the A.C. motor, the motor speed can be slowed to stop, reversed, "powered down" or powered up on a speed or torque scale depending on the application desired at that moment in time.

In our conveyors case, the VVVF motor is then coupled directly to the drivehead gearbox input shaft thus providing the torque to power down or power up to the conveyor drive pulleys.

The reliability and accuracy of the VVVF system & technology used to be questioned.

In some cases it was deemed "Black Box" technology and avoided from fear & ignorance.

Today, VVVF technology is more reliable than your television set and half as complicated.

A typical 500kW VVVF power module

DESIGNING THE CONVEYOR AND THE BRAKES.

….DESIGN & AUDIT'S

Nepean Conveyors used its own in-house conveyor design software to develop the conveyors design for costing and, once the project got under way, to finalise the preliminary design.

Once Nepean was happy with it's design strategy, a second "arms-length" opinion was sought from Watkins Godwin on the dynamic performance of the conveyor along with a third opinion by way of a dynamic model provided by Dr. Alex Harrison.

All models and results were compared and assessed prior to proceeding with detail & manufacture.

……***CONVEYOR LAYOUT.***

Due to the immensely variable loads that would be transmitted from drive pulleys to belt and visa versa, belt to braking (drive) pulleys, the drivehead and emergency brakes arrangement was placed some two hundred meters inbye from the peak of the conveyor in a "Tripper" drivehead configuration.

This gave the conveyor the best dynamic performance under power for uphill-loaded combined with downhill loaded braking.

Technically, the take-up mechanism was best (and originally designed) to be located at the delivery pulley by way of an acceptable counterweight lowered into the coal bin shrouded by a protective 800mm dia. Tube.

This design however was replaced with a 200kN gravity tower, service winch and mass attached to the tail pulley in a tail take-up arrangement which was far more suitable for operational & maintenance issues for the mine.

CONVEYOR STRUCTURE.

The Kyuga mine was expecting a high amount of coal fines to be built up around the conveyor structure & idlers due to the high percentage of fines mined with the Kyuga product. The Dartbrook predecessor mine (lower down) had displayed significant clogging of the offset outer wing idlers in previous experiences. Nepean therefore, provided Kyuga with in-line but overhung off-set five roll 45 degree carry idler set's leaving all carry idlers trailing its cross tube.

Given the 1800mm conveyor structure was to be roof-hung ***and*** at a steeply declined angle, the basic conveyor structure design was reviewed to ensure that structure sections falling into a parallelogram would never be allowed to happen. This was elevated by considerable cross bracing in both the plan and elevation of each structure bay and double splice-bolting all structure bay joints.

The KD01 conveyor's capacity of 4,200 t/p/hr was deemed volumetrically, quite conservative for the 1800 mm belt width. The mainstream straight carry runs of conveyor structure were provided at 45 degree's five roll, however, at the conveyors peak convex radius of 220 meters, the conveyor belt profile was "laid out" to 35 degrees in an effort to avoid stressing the belt edges in tension.

CONVEYOR BELT.

Following appraisal of both Fabric plied and Steel cord belt, the benefits and pitfalls of each given KD01's specific nature & operational requirements, the ST1250 6+5 was chosen with a protective fabric weave provided on the top side of the cables to deflect minor tramp intrusion.

A second benefit of the Steel Cord was the "stiffness" the belt would provide in dynamically demanding situations resulting in less take-up movement in such confined spaces as the conveyor would be working in.

The third benefit came from the fact that the steel cord belt splice would out - live the fabric belt splice and as KD01 was the "Jugular Vein" for the Kyuga and Piercefield Project's, nothing less was acceptable.

EMERGENCY BRAKES.

The normal VVVF controlled ramp-up start of ninety seconds and power-down to stop "braking" cycle was provided via the "Four Quadrant" VVVF drive stages.

In simplistic terms, the VVVF drivehead controller was so designed for the KD01 conveyor that under full load downhill and during a "Normal" stopping cycle of sixty seconds, the two 500kW electric motors and their respective VVVF drive stages provide an extremely well controlled 1000kW braking cycle transmitted in reverse, through the drive gear reducers to the conveyor drive pulleys and then ultimately to the belt to stop the conveyor.

This system prevails of course, when power is available.

In the event however, that a loss of power braking cycle is required, the KD01 conveyor is equipped to do so via twin (Primary and Secondary) 160 kN/m oil immersed multiple disc, multiple pad brakes designed, built & serviced by our company.

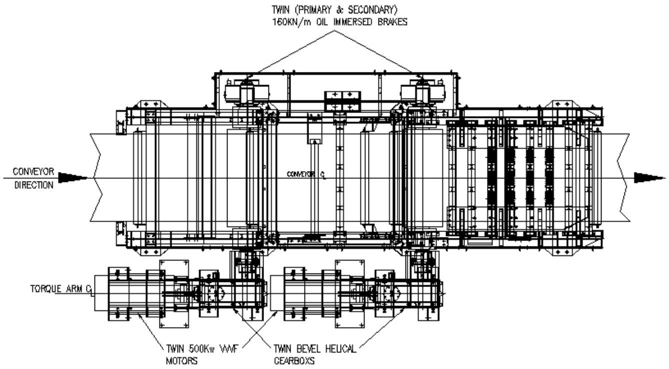
One of the two 160,000 Nm oil immersed brakes.

The Kyuga KD01 conveyor falls within the requirements of AS (Australian Standard) 1755-2000 which, when considering brakes or braking mechanism's in an underground coal mine require that "Where a braking or anti-runback method is required, a second device shall be provided in back-up to the Primary device".

Given that in a loss of power condition, the VVVF power-down capability does not fail-to-safe, it then follows that the VVVF braking capacity could not be considered Primary nor secondary means of emergency braking.

It then followed that whatever mechanical fail-to-safe braking method were used needed to be duplicated to the same power, torque and tractive effort through from drive (or brake) pulley to belt under any condition.

The final tripper drivehead arrangement is shown below.



A further requirement of AS1755-2000 where braking power & torque are concerned is that the braking mechanism must be proven to have a 1.5 safety factor over and above the maximum theoretical demand.

In the KD01 case, the actual theoretical highest demand (in terms of braking torque) was 94k/Nm for sixty seconds.

Therefore and after considering the requirements of AS1755-2000 along with Kyuga Coals and our own risk assessments, Nepean elected the twin, but independent 160k/Nm brake & pulley assemblies.

One would be the primary brake (elected as the secondary drive pulley unit)

One would be the secondary brake, potentially; never to be used (elected as the primary drive pulley unit)

Two requirements that evolved from dynamically modeling the conveyor in all its possible load conditions were:

- The braking power needed to be applied optimally at 0.5 sec. from power loss outside of which, massive transient belt tension waves would be expected. (The elected use of the Nepean multiple piston brake arrangement ensured rapid engagement and rapid evacuation of oil from the operating brake pack to ensure the required 0.5 second engagement was achieved)
- With a peak demand of 94k/Nm, sudden & full application of the installed total of 320k/Nm braking torque would ***not*** be good for the conveyor's well being.

The first point became a reasonably easy part of the oil-immersed brake and hydraulic power pack design; the latter however seemed quite complicated at start, however then novel and simplistic in design.

The first step in designing our primary and secondary brakes control circuit was to instruct the Primary brake when to and how operate with no power.

Given a known belt 100% belt speed of 4 m/sec and a design capacity of 4,200 t/p/hr, Nepean fitted a hydraulic pump to the first motion cross-shaft of the secondary gearbox and provided a fail to safe measurable hydraulic flow system that measured belt speed driven by the gearbox pump. I.E.: Belt speed 4/m/sec = 1201 r/p/m @ 24 l/min

First overspeed = 1441 r/p/m @ 28.8 l/min or 120%

Second overspeed = 1681 r/p/m @ 33.6 l/min or 140%.

Secondary gearbox overspeed pump.

At the appropriate flow rate and not to be confused with slight belt over-speed, a hydraulic logic would operate at 28.8 l/min (or 120% belt speed) thus detecting a continuous & undesirable overspeed situation, thus diverting oil flow to initiate pressure control to the operating circuit of the primary brake.

With this hydraulic logic, there was no need for battery back-up or residual power of any kind and therefore fully complied with Kyuga Coals requirements.

The next step was to have the means to provide 160k/Nm of secondary back up braking torque in the event that the drivehead lost its VVVF power-down and after the lights and power went out, have the ability detect failure of the primary brake before doing so.

The second braking and pulley system is identical in every manner to that of the primary from a mechanical viewpoint.

***The secondary brake with the primary brake torque-arm saddled for hydraulic pressure*.**

The secondary brake control hydraulic circuitry however is prioritized over by way of a hydraulic pressure lock generated mechanically by the primary brake's torque arm rotational force.

In short, while ever in an emergency situation, the primary brake is operating (to stop the conveyor), its torque arm generates hydraulic lock pressure to dis-allow the secondary brake to clamp on & complicate the matter.

The moment hydraulic lock pressure is faltering or not present, the primary brake would be deemed to have failed and over-speed hydraulic control flow is re-directed to the secondary brake control circuit thus engaging the secondary 160k/Nm of emergency braking power.

BRAKING CHECKS & TESTING.

As the VVVF power-down system and the mechanical braking system were deemed so critical to the safe & guaranteed operation of the KD01 conveyor, braking system and hydraulic control system, two checks were designed, tested and installed to measure and test the system.

The first was to independently check the torque rating and operation of each of the VVVF power-down stages along with its 160k/Nm mechanical oil immersed brake.

Prior to each third conveyor re-start and programmed as such (given no-load), the Brake # 1 will release leaving Brake # 2 applied. The corresponding 500kW VVVF Motor # 2 would ramp up to 90% torque over ten seconds while the control speed circuit seeks for pulley motion. Where no motion is detected, the same "Brake operational" test is run through the opposing Brake # 1 and Motor # 1 drive assembly and only on successful completion of "Brake operational" testing does the conveyor logic allow the KD01 to progress to automatic start.

Following a rigorous risk assessment of the conveyor, further on-board test equipment was provided for regular tests to fully functional test the 100%, 120% and 140% overspeed detection and brake application as described above while the conveyor was at standstill or under maintenance.

To do this, Nepean provided for each 160k/Nm brake an independent 4kW VVVF motorized, hydraulic power pack provided in-line with the hydraulic overspeed system.

Given the power pack is provided at variable speed, the pump flow rate can be very accurately simulated (as would be driven by the main pulley gear reducer during an emergency) to force the primary brake to operate and then, given manually prompted "lack" of braking torque, the secondary brake to operate in back-up to the Primary.

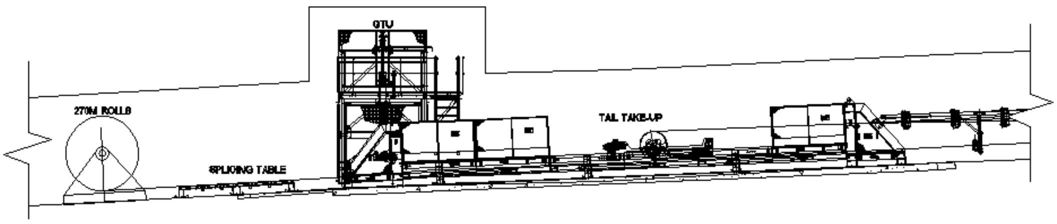
MANUFACTURE AND INSTALLATION OF KD01 CONVEYOR.

The Tripper Drivehead, VVVF 1mW sub-station and twin 160k/Nm brakes were all installed at a location two hundred meters inbye from the conveyors "peak" at a cut-through accessible from both sides of the KD01 conveyor heading.

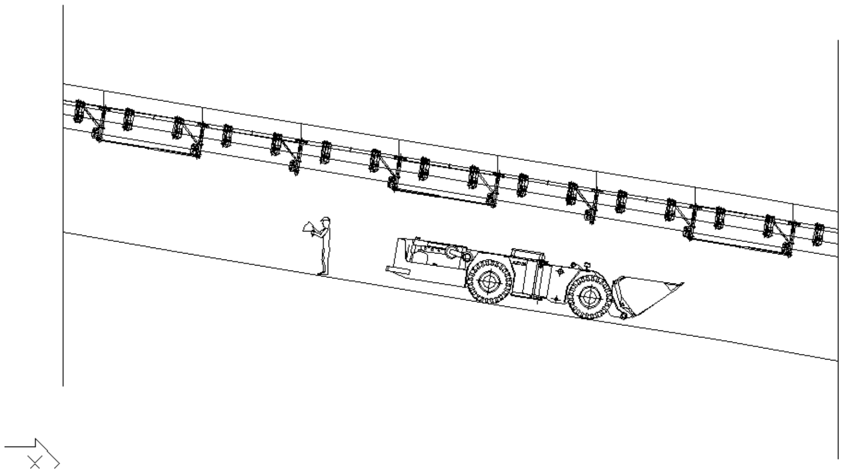
The Tripper Drivehead, VVVF power modules and Brakes

The tail take-up was installed with a 22,000kg mass adjacent to the tail take up allowing the steel cord belt to be run on from the inbye tail end.

The new belt was presented in 270m rolls to the tail of the conveyor, hot vulcanized spliced prior to being pulled into the KD01 conveyor system.

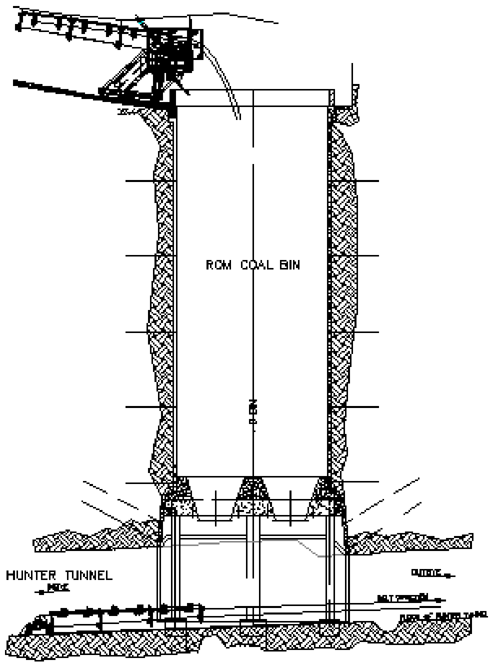


The majority of the five roll in-line carry conveyor structure & idlers were roof mounted with the intent that 90% of the KD01 conveyor would be underpassed by road traffic for access, road travel & conveyor maintenance.



The delivery and lowest point of the decline conveyor delivers product at the rate of 4000t/p/hr from a full maintenance platform and delivery station into an 8000 tonne elliptical underground bin.

The product is then, in turn, presented to the existing Hunter Tunnel conveyor & infrastructure.



The entire installation took sixteen weeks to complete including civils, concrete & sumps, mechanical and electrical equiptment.

COMMISSIONING AND TESTING OF KD01.

Commissioning of KD01 conveyor consisted of four phases:

- Live testing of all mechanical, hydraulic and electrical sub-components along with their independent electronic or hydraulic control logic prior to running the conveyor with belt speed
- Empty belt speed commissioning of KD01
- Loaded commissioning of KD01
- Full load-power loss brakes testing of KD01

LIVE TESTING.

Check wiring then rotational live testing of the conveyor systems various mechanical, hydraulic and electrical sub-components along with their independent electronic or hydraulic control logic took five days, using afternoon and night shifts to act and revise any anomalies that were encountered during the process. The planned time for these functions and components to run their tests was a full seven-day week leaving us a little ahead of schedule.

A great deal of temporary test equiptment, strain gauges, load cell's was produced and fitted during that week to measure & record mechanically & electronically as much data as we felt necessary to capture any abnormality once KD01 was put into action.

EMPTY COMMISSIONING.

To commence empty belt commissioning, the two 500kw VVVF drive stages were selected to 10% belt speed and with observation manning at the tail-take-up, VVFF substation, tripper drivehead, peak convex curve, delivery station and staged at every 200 meters of conveyor straight length, the belt was brought up to 10% speed and with very little, or no off tracking encountered, left there for two hours prior to stopping for inspection.

Data was gathered from the 10% run, the conveyor sub components inspected and a first-run commissioning meeting held to summarize, the only outcome of which was that the theoretical power to drive the conveyor Vs the actual was expected to be some 10% lower than actual. This was put down to "breaking in" the new belt and as anomalies such as these had been experienced many times in other new fabric & steel cord conveyors produced by our company.

In readiness for the second day of empty commissioning, Nepean had called tenders for belt splice scanning with the intent of providing an original, then on-going, six monthly rechecking of an original splice and steel cord cable scanned "footprint".

A local Hunter Valley specialist was selected and engaged to set up the required scanning equiptment for empty commissioning day two.

Again KD01 was brought up to 10% belt speed and this time run for nine hours with minimal manning around the conveyor.

The highlight of this exercise was the belt cables were scanned & numbered along with each belt splice.

The splices and cable quality were "footprinted" and found to have no detrimental inclusions whatsoever and deemed first class.

(As a footnote, the KD01 has now been running for eleven months and at the time of writing this paper, has had it's second scan at six months which proved identical to the "footprint" with no flaw's and will be due for its second operational scan shortly).

On day three of empty commissioning, and with manning at the critical points of KD01, the conveyor was brought up to full speed over a ramp time of 120sec. And run for several one to three hour periods over the next two days during which surprisingly, only minor VVVF, load sharing and control issues were identified & adjusted.

The conveyor was then "run-in" in an empty format while we observed the motor demands reduce somewhat back to within 5% of the theoretical power demands we had pre-calculated and were expecting.

Natural empty coasting times however remained shorter than pre-calculated and would only be deemed to assist in controlling the expected re-generation of power in the down-dip loaded scenario.

LOADED COMMISSIONING.

The primary source of coal product load to KD01 was to be from the Kyuga Longwall followed by up to three development panels.

The Longwall would be capable of a theoretical 3000 t/p/hr followed by three production CM panels at around 400 t/p/hr each, thus culminating in the 4,200 t/p/hr KD01 design capacity.

By the time KD01 had been empty commissioned, the Longwall system was not just yet installed & ready to produce coal, however, the development CM's were in production which gave the Nepean commissioning engineers an excellent opportunity over the next two week period to "ramp-up" the load presented to KD01 from small amounts of development coal through to timed "dumps" from three production units thus giving the Nepean and Kyuga personnel opportunity to build up knowledge & experience of how the control and VVVF system on KD01 would handle the seven minute power swings from positive demand power to regeneration & filtration of power prior to re-directing current back to the grid when the conveyor was loaded down-dip only.

In short and again happily, with only minor adjustments, this phase of the commissioning went without any cause for concern.

The conveyor was left operational for a further two weeks while Nepean left site, with limited use of the development panels and one watchdog operator, while Kyuga completed installation of the Longwall.

Following longwall commissioning and some very light flycuts, Nepean & Kyuga personnel re-attended site to complete the KD01 loaded commissioning.

During the next two weeks, as occurs with most Longwall installations, the productivity was intermittent and unpredictable however, by day twelve, the longwall could produce consistently at 2500 t/p/hr for a web (which well exceeded the KD01 six minute load cycle) along with intermittent development loading which, in our opinion, was providing an average 3000 t/p/hr which although substantial, was still far from the 4,200 t/p/hr design capacity of the conveyor.

Again, very minor adjustments were made to the control; power-down & VVVF drive units.

The conveyor was then put into a "test" mode for a week with recording equiptment, checked regularly for operational issues and the results examined following the weeks longwall and development production.

The conveyor had peaked during that week with 4,000 t/p/hr at a moment when all developments were dumping and the Longwall had hit a good run to maingate.

The results were almost uninteresting.

Positive 600kW demand through to 680kW negative regeneration over a twelve-minute cycle while the VVVF control system performed magnificently.

The only real notable was the regeneration of power was not as high as expected and this had been pre-empted during empty commissioning.

The reason for this was leveled at a higher than expected idler indentation in the soft bottom covers of the ST 1250 belt

FULL LOAD-POWER LOSS BRAKES TESTING OF KD01

Many months of design and engineering intermingled with several in-depth risk-reviews and HAZOP analysis' with input from the Anglo engineering department, the Kyuga project team and Nepean engineering & technical staff had resulted in, what we all believed to be a fail-to-safe, mechanical design and braking system that would bring the worst case loaded KD01 conveyor to a safe, well conducted and stress-less stop in the event of total loss of power.

Our risk review considered the utter worst case scenarios such as, and in order:

- Total power loss thus debilitating the VVVF power-down under the most demanding braking requirement.
- Following attempted application, experiencing total failure mechanically and/or hydraulically of the primary 160k/Nm oil immersed brake?
- Total hydraulic evacuation of the secondary 160k/Nm brake such that its fail-to-safe action occurred totally dry. I.E.: would the last brake have the mass to absorb the braking energy (albeit under destruction) to stop the conveyor safely prior to its disintegration.
- Under the above circumstance, would the brake device qualify for use in an underground gassy environment?

The risk levels that were explored ventured well into the "would not or probably would never happen" many times over however, all parties felt there were to be no better proof than to run a practical test.

In order to be totally committed to a guaranteed outcome and given that we had designed the mechanical braking system with a 1.5 safety factor (as must be to comply with AS 1755-2000) it would follow that a greater load than design load should be exerted on the system under test.

In order to provide this load for test, KD01's VVVF drive stages were slowed to 50% belt speed, the conveyor started and then the mines Longwall was set to cut a full web to maingate. This cutting cycle would provide continuous ROM coal for an eighteen minute cycle at 3000 t/p/hr thus providing the opportunity with KD01 at 50% speed, to present close to double the normal volumetric ROM coal capacity for the full length of the conveyor.

This process continued for a measured ten minutes by which time we believe the KD01 conveyor was ***volumetrically*** loaded to a 4 m/sec belt capacity of between 5000 to 6000 t/p/hr or an average of 35% over design capacity.

At the point where the conveyor was fully loaded end to end, the belt system was stopped and the KD01 conveyor's VVVF drive stages re-set to 100% speed of 4 m/p/sec.

At this point, the KD01 control system had been wired for trends and an array of hand-held battery operated meters, plotters, pressure transducers and battery powered laptops set up ready to record the actions and results of the belt speed, hydraulic flow rate, brake annulus pressure, brake torque and an array of strains and stresses.

The immediate area of the KD01 conveyor was cleared of all non-essential personnel (which left only two people, the Nepean Project Manager and Nepean's chief brakes design engineer), and the conveyor started.

Although the conveyor was in volumetric overload, the 1000kW installed had little problem accelerating the conveyor to full speed given that there was, at that time a great deal of down-dip regenerative effort in assistance.

The commissioning team waited until the maximum regeneration and braking effort would be required which was the point at which the "tail end" of the pre-determined load entered the crest zone of KD01, then switched off power to the VVVF and drivehead sub-station.

As would be expected, the conveyor immediately started to speed up triggering first overspeed at 4.8 m/sec. and as planned, applying the mechanical braking system. It was then calculated the conveyor continued to accelerate slightly after the initial brake application (believed to peak at around 5.1m/sec) prior to being braked down to a stop over a thirty five-second period.

The conveyor system and recorded data was then checked & reviewed prior to re-starting the conveyor to clean off the belt and resume normal production.

SUMMARY,

During the twenty-year history of our company, I don't recall from a technical standpoint, a more challenging "boutique" conveyor system than KD01.

Because of the technically challenging variations in power demand the KD01 would see in operation, during the design phase of the project we encountered several issues where, had we used any technology other than VVVF we would have failed in our risk analysis.

Both no-load and loaded commissioning phases were conducted ahead of schedule and without incident.

The conveyor system passed all our given tests first time leaving all parties involved confident in the design and comfortable that KD01 was fit for purpose.

Had we not used VVVF technology, the control system, conveyor componentry required and the risk would be twice what were needed to bring about a dependable result for Kyuga.

In the eleven months of operation (at the time of writing this paper) the Fault Log History of the KD01 had logged:

- An average of one power loss mechanically braked conveyor stop per week or around forty-four power-loss stops.
- One air conditioning failure stoppage fault.

The power loss stops had been as would be expected, nowhere near the demand of the test power stop however, the reality of the short eleven month history underscores the importance of dependable back-up design.

In summary and in the knowledge & experience of the KD01 installation, wherever our company encounters conveyor opportunities that fluctuate from positive to regenerating demand and back during normal operation, we recommend four-quadrant VVVF control.

References & Thanks to:

- Geoff Sweeny, M.I.Power (Nepean Group) for a well delivered VVVF project & guidance for this paper
- Peter Munday for his effort & guidance (Nepean - KD01 Project Manager)
- David Clarke, (Kyuga Coal Project Manager) with the tolerance of a Saint and for his exceptional talent in delivering the big-picture KD01 package to Anglo-American without missing one detail.