Improving energy efficiency on MG-set driven mine winders

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The continued increase in energy costs forces industry to look for ways to improve efficiency. The industry abounds with stories of energy consumption improvement projects that simply fail to deliver the expected return on investment. Recently, we started examining cost effective methods to reduce the electricity consumption of motor-generator controlled dc mine winders.

The so called Ward-Leonard system became popular as a means to achieve variable speed control before the advent of high power level power electronics. In mine winders, the application often requires controlling the torque applied between a level of -200% up to 200% of the RMS (Root Mean Squared) value and the speed between -100% and 100% (see Figure 1).

Figure 1: Typical duty cycle of a double drum mine winder.

SCR dc drives later replaced MG-sets because they are more efficient when the winder gets up to speed – typically around 90% overall winder system efficiency vs around 82% for MG-set systems. However, there remains a large installed base of MG-set machines. The cost involved to convert these systems simply is not worth it in many cases. Yet we need to find ways to curb our energy consumption.

Methodology

A good method is to analyse the characteristics of the system as well as the characteristics of the application and then look for potential areas of improvement considering the utility rate scheme the customer falls under.

In the case of winders, the following holds true for MG-set systems:

- Most MG-sets are driven by induction machines. Some are powered by synchronous machines. Induction machines run at a very poor power factor when loaded lightly, such as is the case when the winder is idle between journeys or running slowly.
- MG-sets do a better job of converting energy at low winder speeds compared to conventional dc drives. Both methods run at poor power factors at low speeds but dc drives consume a higher level of apparent power.
- There is a huge amount of inertia energy contained in the spinning MG-set. Mine winder motors typically are very slow machines making brush gear and Commutator maintenance much less of an issue compared to the dc generator of the MG-set. It would make sense therefore to slow the MG set when not in use but the impact of accelerating the MG-set back to speed needs to be balanced against this.

As far as the application is concerned, some of the factors playing a role are:

- The winder system ought to be rated for the worst case duty – typically running at full payload during busy periods. But there are often extended periods of the winder sitting idle for several minutes between journeys.
- Many winder drive motors are force ventilated to maximise cooling when the machine is turning slowly or standing idle. Many motor ventilation fans draw as much power as an MG-set at idle.
- Winders produce a wildly fluctuating duty cycle, both drawing power and also regenerating power. This causes engineers to often focus on the peak the actual cycle draws with the aim of...
reducing maximum demand. But we have to remember that the utility metering averages readings typically over a period of half an hour. The energy involved in accelerating a load to speed remains more or less equal irrespective of the acceleration rate. Most mines fall under a utility rate scheme like Megaflex from Eskom. Here we must carefully look at the following aspects:

- The Off-peak, Standard and Peak rate periods applicable during each hour of the day as well as how these periods change during the two high demand months of the year.
- The maximum demand (averaged over a metering period).
- Power consumption (over a metering period) – both reactive and real. It is important to understand that the goal is not merely to cancel out reactive load but to keep the power factor above 0.9. Clear candidates for marked improvement are winder applications like service winders. These machines are in use all the time but even so, spend the majority of the time standing idle between journeys. The journeys are spaced such that it only just is not worth switching the MG-set off and on between journeys. On top of that, many of the journeys carry light loads which further counts against the characteristics of an MG set.

**Strategy**

Metering data was obtained for two such machines and the following broad conclusions are drawn from that:

- One winder registered kWh readings equivalent to only 30% of its rated capacity. This means the machine spends most of its time idle and doing light loads. But you can see from the data that it does work every few minutes, around the clock, so at no time can you identify a period to switch it off. Clearly, having a close look at the production cycle may make it possible to do this so this is one aspect to follow up.

- The same machine draws an almost constant level of reactive power. In general, it makes sense to correct for power factor at a central point as this tends to be more economical because you are able to average many fluctuating loads against each other and perform the function on a greater scale. However, it must be remembered that the reason this reactive power is there in the first place is because for most of the time, we use a massive induction motor to turn an unloaded dc generator.

- The other winder is loaded higher when it does work and it draws very little reactive power during periods of light use. Even so, it draws more kWh in an idle period than the first winder. This is because it is force cooled.

The journey to come up with a solution is not concluded at this stage, but the following prospects are being examined:

- Applying a variable speed drive to control forced ventilation and perhaps even other auxiliaries like the brake system, hydraulics, pumps.

- Evaluating ways of reducing reactive power consumption by the MG-set especially during periods of low demand. Options include:
  - PF compensation.
  - Driving the MG-set with a suitably rated pony motor during periods of low demand.
  - Using a relatively low power slip energy recovery drive with the capability of controlling power factor.

- An extension to the pony motor idea is to allow the MG-set to slow during extended periods of idleness by adding a variable speed drive to the pony motor.

**Figure 3: Slip energy recovery drive with PFC ability.**

At first glance, it may appear that there is no difference between some form of PFC versus reducing the amount of reactive power drawn. Using a smaller drive motor for when the MG-set is idle does reduce the kVA consumed but once power is required, you switch back to the main MG-set induction motor and your kVA load shoots up once more. But remember, the goal is not strictly to minimise kVA load, but to maintain the PF above a level of 0.9. So, under load, it does not matter if the kVA load shoots up – you are paying for kWh. It is
true that PFC will reduce the kVAR load all the time but this does not deliver any additional economic benefit. By removing some kVAR loading, the existing PFC capacity is liberated to assist with other loads on the system.

Winder number one is a 2 000 kW rated mine winder and it draws a steady 440 kVAR worth of reactive load regardless of its usage. At idle times, over 300 kVAR load can be shed.

Secondly, loads like the ventilation fan (around 30 kW or more) consume about the same level of mechanical power as does a spinning MG-set at idle. These units would typically be implemented as DOL (Direct on line) starters so the resulting high inertia of the fan itself translates this into a system one does not wish to stop and start all the time.

But the increasingly more economical ac drives available today make this and other auxiliary drives candidate applications. Analysing the data shows a total of 5% to 20% of the monthly consumed power goes into auxiliary loads like these on winders that perform intermittent duty.

Conclusion

Once again it goes to show that the most obvious way to improve efficiency (in this case replacing an MG-set with a dc converter drive) is not necessarily the only way to achieve meaningful improvements. It is vital to look at the utility rate scheme, the application and the characteristics of the technology employed to identify strategies that will deliver on the feasible investment available.

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