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Variable Speed Diesel Generator (VSDG)

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Introduction

Research into VSDGs was motivated by the desire to improve performance at part load, in terms of efficiency and running cost. VSDG have been proposed as a technological solution for the diesel generator market for over a decade. With recent cost reductions in power electronics, the VSDG has started to make more economic sense [1].

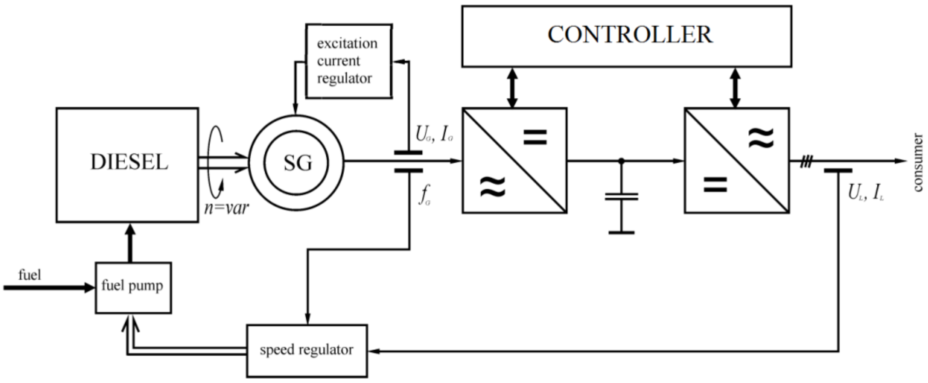

Figure 1. Schematic diagram of VSDG.

Advantages

The constant speed mode of operation is never more efficient than the variable speed and only ever matches it at near full load. Variable speed operation of a diesel engine is beneficial in terms of efficiency and therefore fuel consumption. Variable speed operation also allows more power to be produced from the same sized engine in most cases, as the speed can be increased above that of the set constant speed.

As well as being more efficient and cleaner, variable speed operation can also be quieter than constant speed, given that it runs at lower speeds when part loaded. This can be important for systems close to properties that run during the night, when the diesel engine load is likely to be low and noise pollution is more of a problem. As with the pollution control, the operating set points can also be optimised for the quietest running conditions.

A number of advantages are created by using a PMG, they can be very beneficial in standalone grids where there is no readily available supply of electricity for excitation. Most variable speed generator concepts and actual systems use PMG.

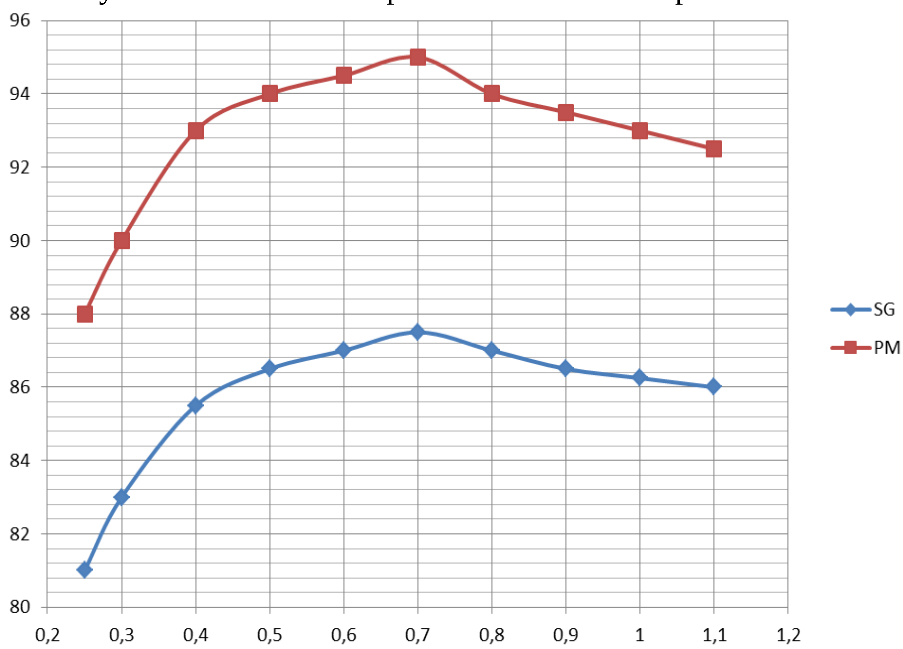

Figure 2. Generator efficiency.

This allows them to run more efficiently, especially at lower loads when excitation power becomes a larger proportion of the power balance in a conventional generator (synchronous & asynchronous).

PMG have the ability to be more reliable than conventional generators, because they are selfexcited and can be mounted directly on to the engine crankshaft, which removes the slip rings and bearings fitted to standard genset that would otherwise need regular maintenance.

On Figure 2 it can be seen that the permanent magnet generator is more efficient than the synchronous generator for all load situations, At part load, the Permanent magnet generator performs much better than the synchronous generator, never dropping below 90% efficiency which is greater than the maximum achieved by the synchronous generator. Using a PMG gives the complete generator and converter system an overall efficiency of around 85-90% (0.95*0.93=0.88), which is comparable to a synchronous generator on its own.

Disadvantages

All variable speed generators need converters to control the voltage and frequency of power supplied to the grid. A good converter can run at up to 95% efficiency, but all have losses associated with switching devices and static elements such as capacitors, diodes and inductors. Permanent Magnet Generators (PMG) are more efficient than other generators, owing to their absence of electrical excitation, this allows them to reinstate some of the loss from the converter.

The additional cost of power electronics and PMG dramatically increases the cost of the diesel genset, but also increase the control requirements, complexity and therefore total cost.

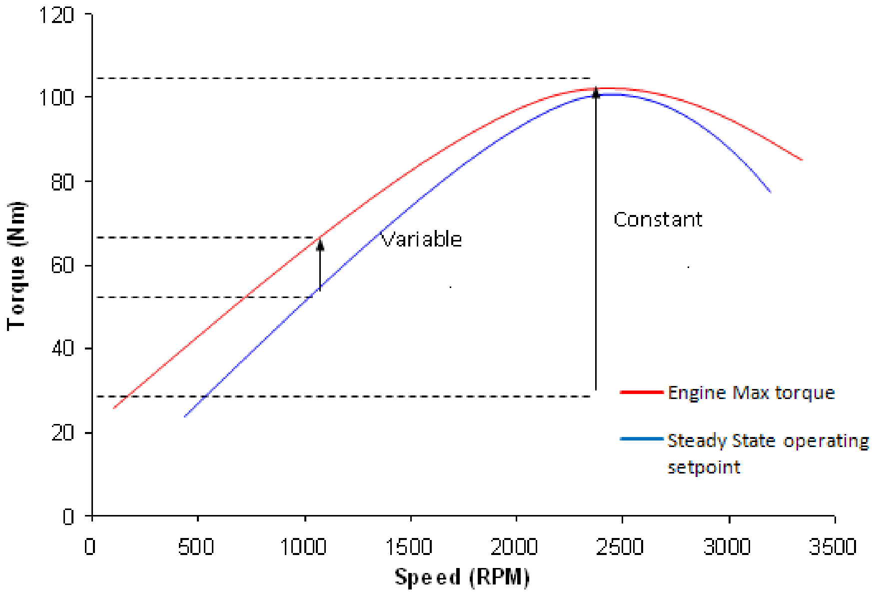

Figure 3. Diesel Generator Loading.

The dynamic performance of the VSDG is a potential disadvantage, as it can be compared at any given instant to a constant speed diesel generator with the maximumoutput related to the set rotational speed. Therefore, the generator seems to increase in size as the rotational speed increases up to the maximum power.

The additional torque available at any given moment is the diesel engine maximum power (top line) minus the steady state operation set point (bottom line), demonstrated by the variable speed arrow in Figure 3 [2].

The torque available to meet step load increases for the constant speed generator (right arrow) at the same power starting point as the variable speed operation (left arrow), is much larger. The instantaneously available torque significantly affects the generators dynamic stability. If a step load above the available power is applied to the generator, it will not be able to meet the demand quickly and the diesel engine could stall causing a blackout. For a small generator sized for a community of 10-15 households, the equivalent demand of two electric kettles (3 to 4kW) being switched on or a small drop in wind speed for a high penetration wind-diesel system could be enough to seriously compromise the VSDG stability. To compound matters any load increase may initially decrease the engine speed leaving less available power to meet the load change. If a step load increase is large enough to use all the immediately available power, the generator would then be in a very dangerous/unstable condition, as it would be unable to accelerate to the new set speed, and even a small load increase after that would be capable of crashing the system.[3].

VSDGs are a new technology and therefore the reliability of the systems has a level of uncertainty attached to it. This is a significant obstacle to up take, especially in remote communities where it would be used as the main source of power.

Although power electronics are generally seen as reliable and require very little if any maintenance, their addition can also take away the communities ability to fix faults impacting on their independence. The modularity of many power electronic components also means that even if a suitably qualified person is available to find faults and carry out repairs, spare parts would need to be readily available. As these components are often expensive, they are not likely to be stockpiled and so they would need to be ordered in. Many power electronic components are in short supply and therefore can have long lead times adding to the transport delays, which can also affect these remote areas.

Summary

To summarize, conventional diesel gensets are a reliable but expensive way to supply electricity. The main reason for their expense is the price of diesel fuel, which is further aggravated by the inefficient running of the diesel engine at part load. To overcome this problem, the running of the diesel engine at the optimum speed for the load (i.e. variable speed) has been suggested. Although this is not a new idea, the increased cost of the variable speed diesel generator, mainly because of the need for power electronics, is only just starting to be offset by the fuel savings. Variable speed operation of the diesel genset is expected to be beneficial for most offgrid community applications.

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