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Fast start reciprocating engines in the flexible power generation

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Abstract

The Energy transition towards renewable energy is going to need an increase in flexible power generating capacity. Different approaches are taken into consideration in different countries. The paper analyzes the Spanish case and the UK case. One of the technologies that could be key in providing this extra flexible capacity when needed are reciprocating engines that could make use of different fuels of that (hydrogen, sewage, landfill, natural gas, etc.). Reciprocating engines fast start and flexible capabilities are presented based on different engine tests already done. Reciprocating engines could be a proper renewable solution in the future if they are consuming hydrogen gas.

Palabras clave: CM, (Capacity Market)

1. Introduction

In the past the energy system could be characterized as a centralized energy system with big fossil fueled centralized power plants that by means of a transmission and distribution network supply the energy to the end user. Nowadays new technology and solutions are changing the way the energy system is operated. The importance of wind power renewable generation, new technologies and the CO2 reduction importance are making a transition to a more distributed power generation system. This trend to renewables can be seen clearly in the top power generation companies.

The Spanish energy market and the UK energy market are shown as two alternative cases in this article. Two of the most promising flexible energy alternatives are shown. The reciprocating engines are studied as one of the possible alternatives for an increase in the flexible power generation that has been started to be used in the UK market.

2. Spain Energy System Overview

In Spain the total installed power capacity nearly doubles the maximum hourly demand. Although the installed wind power capacity is around 23% in the maximum hourly demand the use of wind energy was reduced to 11.7% and that coal power generation was in fact an 18.5%. This means that although wind power or other ways of renewables power generation has been introduced the dependency of coal is still important due to the intermittent characteristics of renewables technologies.

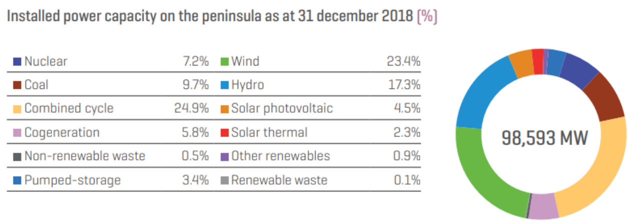

Figure 1: 2018 Energy power capacity (REE, 2018).

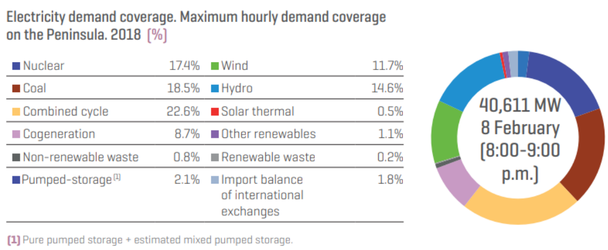

Figure 2: 2018 Energy demand coverage (REE, 2018).

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Looking at above figures in Spain it seems that if the renewables energy percentage is increased in order to cover 80% of total demand, then a 20% is left to Nuclear and combined cycle, if coal plants will be closed in the future before reaching 2050. The interconnections with other countries are considered as a storage source of energy by REE. The question is what could happen in a scenario where all the countries rely in the interconnections and power capacity of others with a similar energy mix. Probably it makes sense to diversify the energy flexible capacity and to provide some critical back-up system. It seems no clear the planned flexible capacity in Spain regarding other energy storage systems like batteries or the use of reciprocating gas engines as in the UK case.

In the Spanish Canary Islands the pumped storage plant of Soria-Chira it is being constructed. It will provide 200Mw of energy capacity that will be pumped with the extra energy produced by the wind in the Canary Islands.

3. UK Energy Overview

The UK energy systems has experienced a big change in the last years. For example, UK government has introduced a called Capacity Market to ensure the UK's electricity supply can meet the demand in cases when the renewable generation cannot be used due to low wind, etc. and in order to reach the decarbonization of the UK for 2050. So, the Capacity Market is planned to prevent possible future blackouts during times when demand is high, or renewable generation is low. Due to the increase of the renewables in the UK energy mix Aurora Energy Research has estimated a needed increase in flex capacity up to 2050 in relation to the percentage of renewable production (Aurora Research, 2018). Two technologies that are planned to provide the major part of the flexibility in the UK case are Batteries and Gas reciprocating engines.

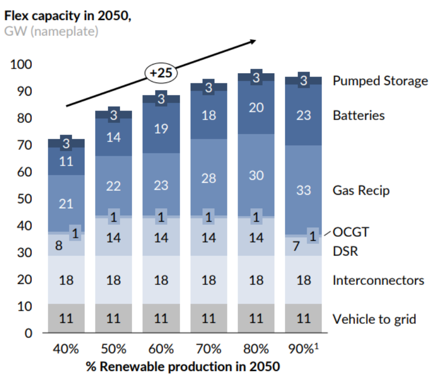

Figure 3: Flex capacity needs vs % Renewable Energy production (Aurora Research, 2018).

If the flexibility energy generation capability is low, then the percentage of renewables can drop from 80% to 40%. The flexibility and energy storage have the potential to save between £2 billion and £7 billion per year on average by 2030.

4. Reciprocating Gas Engines Fast Start Capabilities

It seems that two of the most key technologies for providing flexible capacity are going to be batteries, able to maintain load for 1-4 hours, and reciprocating gas engines. There are also other interesting technologies like hydrogen produced with the excess of renewable energy that could be stored and then supplied to the gas line for providing energy for example to reciprocation gas engines.

Batteries starts to be a suitable energy storage solution to assist with these challenges. Companies like Fluence, Tesla, etc. provide these systems and Fluence for example nowadays have a capacity of more than 700Mw available.

One of the biggest problems with batteries is that the energy supply is limited to 1-4hour and it is not so uncommon to have a week without wind in the UK that could affect energy system. So, it seems that also gas engines could provide that flexibility power generation only when needed at a low cost. Compared against low ramping capabilities of big turbine based combined cycle gas power plants reciprocating gas engines can start and provide full power in less than 30-60 seconds. They are not as fast as batteries and not suitable for continuous fast frequency grid correction but once they run, they are not limited to a small number of hours. Also, on a site made of several reciprocating engines several could be stopped while others run at full power at their highest efficient point, so the flexibility and modularity of a reciprocating engines plant is interesting. There is potential for development and R&D in order that those engines could be modified in the future for using other renewable fuels like hydrogen.

Siemens Gas Engine business has developed last year specific engine configurations optimized for different fast start capabilities and increased efficiency levels due to the UK demand. Below can be seen the power capabilities of an SGE-56SL Engine delivering full power (1Mw) in less than 30seconds. One of the key components added to the engine is an increased water preheating system so that the engine water temperature is hot enough in order to facilitate the full power capabilities in a short time and to reduce big thermal changes on mechanicals components that could reduce their lifespan. The major pros of a power plant made of gas engines against a turbine power plant are:

- Modularity: A fault on one engine does not affect the load capabilities of the rest.
- Fast start: Combined cycle power turbines normally have full power time around 30 minutes and are not able to operate properly below 30-40% of their load capabilities.
- Decentralization concept: As gas engines operates with low pressure admission gas needs it is not needed compression gas and the infrastructure is reduced reducing as well the CAPEX and OPEX.
- Reduced load operation: it is possible to operate the engines at reduced load operation. This makes ideal for compensating the intermittent renewable power generation.

On the contrary, in case long full power generation is needed running a combined cycle power plant has higher efficiencies and it is normally more reliable due to the turbine rotating machine concept compared against the stroke mechanism of the gas engines.

Siemens has done extensive test and fine-tuning control optimization to find a good starting capability in gas engines. Below are shown some results in the case of SGE-56SL engine configuration. The minimum reached time is 19.2 seconds, the maximum 30.6 seconds and the average 24 seconds. In the starting profile three phases can be differentiated. Phase 1: time from zero speed until engine is over 300rpms. Phase 2: time from 300 rpms until the engine is synchronized against the grid. Phase 3: time once the engine is synchronized up to full power. In the worst case, adding the worst cases per phase, 34.6 seconds have been reached. The total time was 25.2 seconds for the first start at the morning day and 23.8 seconds for the rest of the starts done during testing. The average start time is 5 seconds.

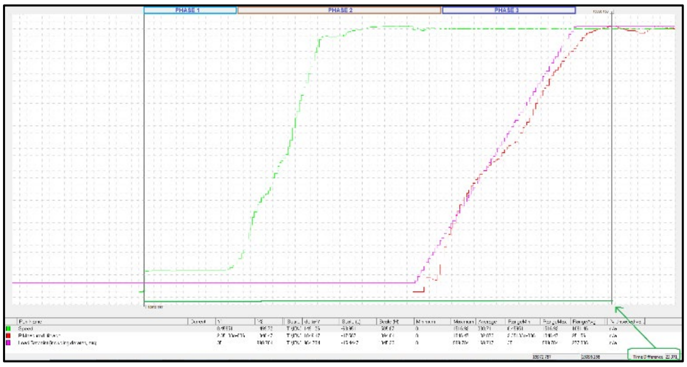

Figure 4: Power-ramp actual profile SGE-56SL Engine (Siemens Gas Engines).

The synchronization time is the one that varies the most. The tests have been done with the local network frequency conditions in Spain, which may vary in England. The phase 3 rise time once synchronized up to full is 7.5 seconds on average. If we look at the normal distribution and the accumulated one, we see that in 99% of the cases the start and full load is reached in less than 30 seconds. In 87% of the cases in less than 27 seconds and in 65% in less than 25 seconds.

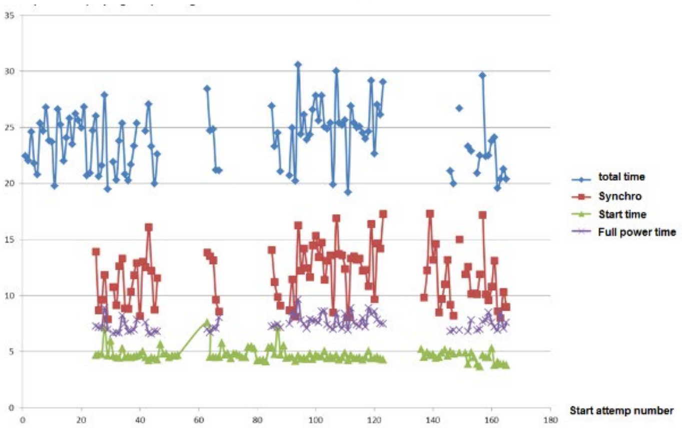

Figure 5: SGE-56SL starting phases time analysis

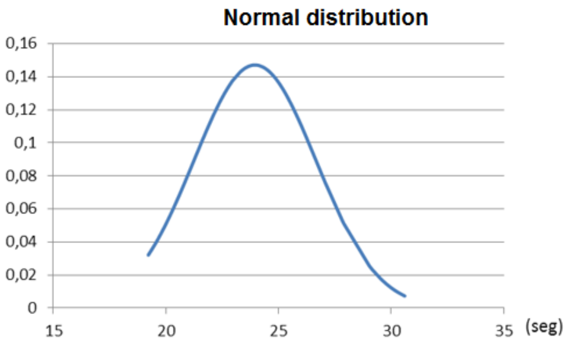

Figure 6: Full time normal distribution (Siemens Gas Engines).

5. Conclusions

The results demonstrate the fast-starting capabilities of reciprocating engines with times from starting to full power that are less than 30 seconds. In the future there is potential developments so that the engines could use hydrogen instead of natural gas. Further test could be done with hydrogen in order to compare fast start capabilities.

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