Impact of change in GB generation mix on frequency control

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I. Introduction

In the GB, about 13 GW of conventional power plants are due to shut down by 2020 and a total of 20GW by 2030[1]. The total generation capacity in 2030 is to increase to about 150GW[2] of which a large proportion will be from renewable energy especially offshore variable speed wind turbines (about 30GW). These will be replacing the conventional synchronous machines[3]. Synchronous machines are sensitive to frequency variations of the AC grid and variable speed wind turbines are not. The major component of the wind turbines are the power electronics converters, which decouples their inertia from the grid and make them less sensitive to frequency variations. Thus, there is a decrease in the total power system inertia. This causes an increase in the rate of change of frequency and the system is exposed to several stability and operational risks.

This paper studies specifically the GB grid and how the expected changes in generation mix will affect the inertia thereby, the frequency control. The system frequency response is studied on the single-machine infinite bus model. Also, a 3-machine model being developed to study the frequency behaviour is introduced.

II. Estimation Of Future Inertia Constant In GB

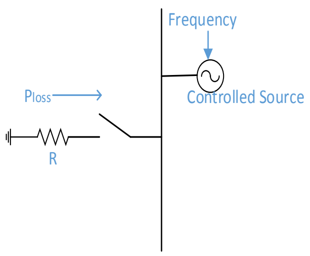

Figure 2: Single machine infinite bus model

In this section, the inertia of 2020 and 2030 generation mix under the gone green and slow progression scenarios of the National Grid Future energy scenarios are analysed and compared. The Gone green scenario assumes that there would be a growing economy which allows for more affordability and sustainability thus there would be huge investments in renewable energy.

The slow progression scenario places emphasis on high sustainability with low affordability. Thus, there is less investment in renewable energy. Table 1 above shows the estimated inertia constants for the years.

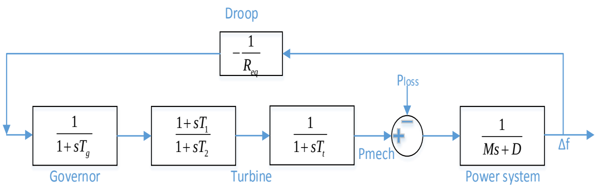

Figure 1: Simplified GB model

Table 1: Inertia constant for different scenarios

Scenarios	Equivalent Inertia constant H(s)
2013/14	3.932
Slow Progression 2020	2.797
Gone green 2020	2.536
Gone green 2030	1.899

III. Single machine infinite bus model

The single machine infinite bus model in the figure 3 below was developed to represent the GB system. The machine frequency is controlled through a set of transfer functions which shows the behaviour of a synchronous plant such as coal, nuclear, hydro, gas etc. In the event of frequency deviation, the plant responds and the power output is increased.

R_{eq} = equivalent droop of all generators connected
T_g = Governor actuator time constant = 0.2s
T_1 & T_2 = 2s & 12s respectively = lead and lag time constant for transient droop compensation
T_t = turbine time constant = 0.3s

The simplified GB model has been used by several references in providing frequency response.

IV. Case Study

When there is a disturbance to the power system, there is a drop in frequency which depends on the inertia and governor characteristics. Here, the frequency deviations and RoCoF for the different scenarios are obtained using the single machine infinite bus model. A loss of infeed represented by the addition of load of 1800MW is simulated to see the frequency response.

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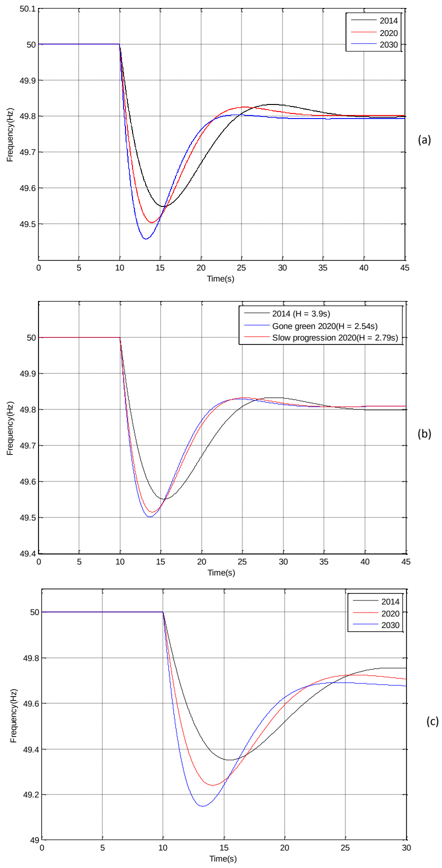

Figure 3 Frequency response (a) 2014 GB power system characteristics 2020 Gone green & 2030 gone green scenario (Peak demand) (b) 2014, 2020 gone green & 2020 slow progression scenario (Peak demand) (c) Average demand 2014, 2020, 2030 gone green scenario

V. 3-machine model

A 3-machine model was developed. With 3 synchronous generators representing England, Scotland and Wales. It consists of exciter and governor control to be able to fully understand the inertial response.

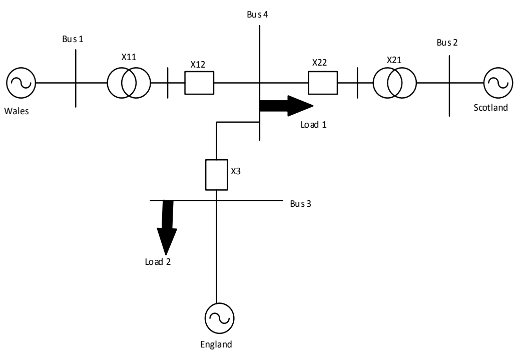

Figure 4: The 3-machine model

The 2014, 2020 and 2030 gone green scenario were simulated on this 3 machine model and similarities in frequency deviation were obtained. The RoCoF were different from the simplified model.

Table 2: Simplified model vs 3 machine model results

	3-machine model		Simplified model	
	RoCoF (Hz/s)	Frequency deviation (Hz)	RoCoF (Hz/s)	Frequency deviation (Hz)
2014	0.10	0.46	0.14	0.45
2020	0.15	0.50	0.20	0.50
2030	0.21	0.55	0.24	0.54

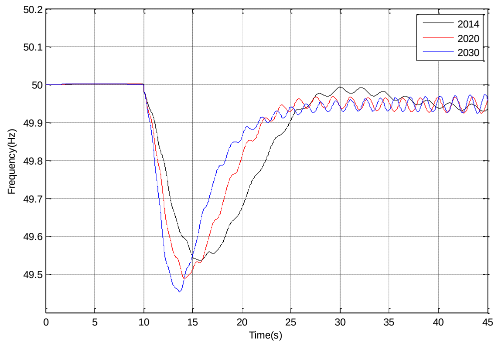

Figure 5: Frequency response 2014 vs 2020 gone green vs 2030 gone green (peak demand)

The 3 machine model is still being developed and it will provide more insight of the grid and also power transfers from the various networks.

VI. Conclusions

This paper analysed the frequency response characteristics of the GB grid using the 2014, 2020 and 2030 generation mix under two different future energy scenarios. It is observed that under the average demand scenario the frequency drops below the operational limits at the 2030 gone green scenario. Therefore, additional frequency control has to be provided by the system operators. The problems brought about by the low inertia constant of the grid include but are not limited to frequency curtailment issues, stability and RoCoF relay setting changes[4]. Solutions are wind turbine and HVDC converter control which is being studied in future work, also demand side response[5] and fast energy storage[6].

References

[1] National Grid, "UK Future Energy Scenarios 2014," *Energy*, no. July, p. 220, 2014.

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