## Joint GCRP/DCRP Workgroup Frequency Changes during Large Disturbances

Update to Distribution Code Review Panel on Thursday 5 December 2013

### Introduction

The Consultation entitled "Frequency Changes during Large Disturbances and their Impact on the Total System" was published on 15 August 2013 and closed 27 September 2013. The consultation presented proposals to change the recommended RoCoF protection settings in the Distribution Code and ER G59 to 1.0Hzs$^{-1}$ for distributed generators at stations of a capacity of 5MW and above.

A significant number of responses supported the proposed change. An equivalent number of responses challenged aspects of the need for change. A number of material concerns were raised particularly with respect to synchronous generators and the implementation costs faced by owners of existing installations. The workgroup has met twice, on 21st October and 25th November, to review responses and to re-evaluate the case for change.

### Revised Case for Changing RoCoF Settings

A number of respondents suggested that further information was required on the costs of implementing the consultation's proposals and the benefits accrued as a result. The workgroup have considered a revised assessment which was developed after consideration of consultation responses. The revised assessment quantifies:

- Savings in Balancing Services costs* by:
  - changing all RoCoF settings to 1.0Hzs$^{-1}$;
  - changing RoCoF settings on distributed generators at stations of 5MW and above only; and
  - changing all RoCoF settings to 0.5Hzs$^{-1}$; and
- Estimated costs of implementing a protection setting change:
  - on distributed generators at stations of 5MW and above only; and
  - at all distributed generators.

The assessment is intended to quantify the case for a protection setting change rather than to represent a forecast. As such, it deals with uncertainties by taking a pessimistic (ie highest reasonable) view of costs and a pessimistic view of savings (ie lowest reasonable accounting for specific sensitivities). A summary of the assessment is provided in Appendix A. The workgroup's slides on the assessment are provided as an addendum to this paper.

The main conclusions of the assessment are:

1. The savings gained by removing the current RoCoF limit outweigh the costs of implementing change by a large margin, with payback achieved within a year;
2. Some of these savings are lost if a setting of 0.5Hzs$^{-1}$ is chosen. These are at the end of the assessment period (up to 2025); and

* Balancing Services Costs are the day to day costs of operating the transmission system funded through BSUoS (Balancing Services Use of System) charges which are levied on electricity generators and suppliers

3. The savings gained by implementing the proposed change for generators at stations of 5MW capacity and greater outweigh the cost of implementation, with payback achieved in 2 years.

A number of additional points were raised in workgroup discussion for inclusion in the final assessment. These were:

- Although the group felt its recommendations had no adverse impact on the risk of damage to synchronous generators (noting that this was as a result of work and costs incurred to deal with this), it was worth highlighting that the costs of generator damage, while significant for the party concerned, would not have an impact on the case in favour of a change;
- The forecast savings should be considered in the context of overall Balancing Services costs;
- There may be consequential savings (ie reduced frequency response costs) of working to a lower Rate of Change of Frequency which could offset some of the anticipated costs (ie savings may in practice be less but not by enough to affect the case for changing settings);

The workgroup also asked that the assessment clearly states the savings gained from implementing a RoCoF protection setting of $0.5Hzs^{-1}$ on distributed generators at stations of 5MW and above only.

The group noted that consultation responses from representatives of non-synchronous technologies were generally supportive of a change to RoCoF settings to $1.0Hzs^{-1}$ which aligned with the workgroup's discussion in development of its consultation proposals. In addition, the workgroup considered the feedback from its initial industry workshops that a single change was preferred. The group's assessment suggests that relay settings of $0.5Hzs^{-1}$ will need to be re-considered before the end of the decade.

A number of consultation responses suggested that cost-recovery mechanisms should be developed to ensure that implementation costs were targeted appropriately. Workgroup members expressed a range of views but concluded that this issue did not fall within its terms of reference.

**Clarification of Relay Setting**

Specific concerns were raised in consultation responses over the use of the expression 'measurement period'. The workgroup has subsequently developed revised drafting which is more closely aligned with protection relay functionality.

**Recommendation**

The workgroup has come to a conclusion based on the following points:

1. The savings gained by implementing a higher RoCoF protection setting for generators at stations of 5MW capacity and greater, significantly outweigh the cost of implementation;
2. A setting of $1.0\ Hzs^{-1}$ minimises the risk and cost of having to make another setting change in the near future;
3. There is no material difference in the impact on owners of existing and new non-synchronous generators of a setting change of $0.5\ Hzs^{-1}$ or $1.0\ Hzs^{-1}$;

4. There is little material difference in the impact on the developer of new synchronous generators of a setting change of 0.5 $Hzs^{-1}$ or 1.0 $Hzs^{-1}$;
5. There is a material difference in the impact on owners of existing synchronous generators of a setting change of 0.5 $Hzs^{-1}$ or 1.0 $Hzs^{-1}$;
6. Affected Parties need a reasonable amount of time to implement the proposed change.

The workgroup therefore recommend that the following proposal for distributed generators at stations of a capacity of 5MW and greater is taken forward in a report to the Authority:

1. All non-synchronous generators with RoCoF based protection will be required to have a setting of 1.0 $Hzs^{-1}$ from 1st April 2016;
2. All synchronous generators with a completion date on or after 1st April 2016 with RoCoF based protection will be required to have a setting of 1.0 $Hzs^{-1}$; and
3. All synchronous generators with a completion date before 1st April 2016 with RoCoF based protection will be required to have a minimum setting of 0.5 $Hzs^{-1}$.

In each case the delay setting should be 500ms.

The DCRP is asked to approve the workgroup's recommendation.

**All Costs £m (2013/14 prices)**

## Total Balancing Services Cost Summary

| | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Cost of Managing Existing Infeed Loss Risks | 9.5 | 11.2 | 48.5 | 51.6 | 57.3 | 49.1 | 87.8 | 104.2 | 123.5 | 217.8 | 310.4 | 330.6 | 475.4 |
| Total Cost Including New Infeed Loss Risks | 9.5 | 11.2 | 48.5 | 63.5 | 187.0 | 253.4 | 316.5 | 393.4 | 545.7 | 704.8 | 962.8 | 1,003.6 | 1,181.3 |
| Total Cost if Settings are Raised to 0.5Hzs$^{-1}$ or above for >=5MW plar | 8.5 | 10.1 | 43.5 | 58.1 | 181.0 | 248.4 | 307.9 | 383.9 | 535.2 | 692.4 | 949.2 | 991.8 | 1,168.4 |
| Total Cost if Limit is set to 0.5Hzs$^{-1}$ | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 1.8 | 16.2 | 45.4 | 158.4 |

## Total Achievable Savings

| | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cumulative Savings (1Hzs$^{-1}$): 2017 Completion | | | | | 187.0 | 440.4 | 756.8 | 1,150.2 | 1,695.9 | 2,400.8 | 3,363.5 | 4,367.1 | 5,548.5 |
| Cumulative Savings (1Hzs$^{-1}$ >=5MW only): 2016 Completion | | | | 5.3 | 11.2 | 16.3 | 24.9 | 34.4 | 44.8 | 57.2 | 70.9 | 82.7 | 95.6 |
| Opportunity lost for a setting change to 0.5Hzs$^{-1}$ compared to 1Hzs$^{-1}$ | | | | | .0 | .0 | .0 | .0 | .0 | 1.8 | 16.2 | 45.4 | 158.4 |

## Implementation Cost

| | | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Generators at Stations of >=5MW | Cost | | 5.0 | 5.0 | | | | | | | | | | |
| | Cumulative Cost | | 5.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Generators at Stations of<5MW | Cost | | | 15.0 | 15.0 | | | | | | | | | |
| | Cumulative Cost | | .0 | 15.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| Total | Cost | | 5.0 | 20.0 | 15.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| | Cumulative Cost | | 5.0 | 25.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 |

For info:

| | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline GB Wind Capacity In Scenario (MW) | 10,063 | 11,288 | 12,286 | 12,949 | 13,804 | 14,607 | 16,217 | 17,472 | 18,743 | 20,960 | 23,316 | 25,293 | 28,306 |

**Appendix A**

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# Revised Cost Benefit Assessment

WG 25th November 2013

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# Background

- The GC0035 consultation presented a view of the costs and benefits of changing RoCoF protection settings to 1.0Hzs$^{-1}$
  - The benefits identified were associated with Balancing Services Cost savings
    - Estimated at £10m pa with an upper range of £100mpa
  - The costs identified were the costs of making a protection setting change on generators at stations of 5MW and greater
    - a total of ~£7.5m consisting of
      - the costs of changing protection settings at £1.5m
      - The costs of site-specific risk assessments at £2.3m
      - The costs of mitigation where necessary at £3.7m

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# Questions Raised in Responses

- The following points were raised in responses
  1. Do the benefits of a change for >=5MW plant alone outweigh the costs?
  2. Do the benefits outweigh the costs of implementing a setting change for all distributed generators (ie including plant <5MW)?
  3. What's the impact of adopting a different setting (eg $0.5Hzs^{-1)}$?
  4. What are the additional costs for new generators?
  5. What is the cost of damage to generators due to an increase in risk under new settings?

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# Components of the Revised CBA

- The revised CBA is intended to address these points and is made up of the following components
  - An updated projection of Balancing Services costs
    - under the current constraint (0.125Hzs$^{-1}$)including
      - the cost of managing existing infeed loss risks
      - the cost of managing new infeed loss risks
    - the cost of managing to a limit of 0.5Hzs$^{-1}$
  - An updated view of implementation costs for plant at stations of >=5MW
  - An estimate of implementation costs for plant at stations of <5MW

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# Components of the Revised CBA

- The revised CBA does not include
  - The cost of damage to generators due to a change in protection settings
    - This cost would be significant for the party concerned
      - feedback suggests ~£100k per incident
    - However, successful completion of the recommended site-specific risk assessment will minimise this risk of damage occuring
      - The cost of the risk assessment is included in the CBA
  - Additional costs to new connectees of new settings
    - No additional costs have been identified

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# Approach of the Revised CBA

- The CBA is required to quantify the case for a proposed change to the Distribution Code and ERG59
- There are many uncertainties in the evaluation, for example
  - Model uncertainties for future system conditions
  - Incomplete information
- The CBA therefore needs to capture the possibility of a worst case outcome
  - Savings in system costs (Balancing Services) at the low end of our range
  - Implementation costs at the high end of our estimates
- It does not represent a forecast or a statement of expectations

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# Cost of Implementation

- Generators at stations of >=5MW
  - GC0035 Consultation set out costs associated with
    - Changing settings at 150 sites (approx 50% assumed to use RoCoF rather than vector shift or other methods)
      - Of these, 90 were assumed to be synchronous generators and needed a site-specific assessment
      - 40% of these (~20% of the total synchronous generator population) were assumed to require mitigation

| | Protection Setting Change | Site Specific Risk Assessment | Mitigation |
|---|---|---|---|
| Max Number of Sites | 150 | 90 | 36 |
| Cost Per Site | .010 | .025 | .100 |
| **Sum (£m)** | **1.50** | **2.250** | **3.600** |

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# Cost of Implementation

- Generators at stations of >=5MW
  - Latest view of generator data (approx 50% complete)
    - 54 sites with RoCoF, 29 of which are synchronous generators

**LoM Protection Setting Info at DG of 5MW and above (Data Gathered up to October 2013)**

**Capacity (MW)**

| | WPD SW | WPD WM | WPD EM | NPG Y | NPG N | ENW | SP M | Total |
|---|---|---|---|---|---|---|---|---|
| RoCoF <0.2 | 117 | | 29 | | | 89 | 149 | 384 |
| RoCoF >=0.2 | 95 | 115 | 40 | 29 | 38 | 115 | 41 | 473 |
| VS | 120 | 61 | 160 | 23 | 37 | 31 | 70 | 502 |
| I/T | 66 | | | 20 | 17 | 54 | | 157 |
| Other | 78 | 131 | 19 | 154 | 147 | 442 | 30 | 1001 |
| Total | 476 | 307 | 248 | 226 | 239 | 731 | 290 | 2516 |

**Number of Sites**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| RoCoF <0.2 | 12 | | 1 | | | 4 | 5 | 22 |
| RoCoF >=0.2 | 7 | 7 | 2 | 2 | 3 | 7 | 4 | 32 |
| Other | 24 | 15 | 9 | 14 | 14 | 9 | 5 | 90 |
| Total | 43 | 22 | 12 | 16 | 17 | 20 | 14 | 144 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| RoCoF Sites | 19 | 7 | 3 | 2 | 3 | 11 | 9 | 54 |

**Synchronous Generator Sites With RoCoF**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| RoCoF <0.2 | 3 | | 1 | | | 4 | 3 | 11 |
| RoCoF >=0.2 | 3 | 7 | 1 | 2 | 1 | 3 | 1 | 18 |
| Total | 6 | 7 | 2 | 2 | 1 | 7 | 4 | 29 |

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# Cost of Implementation

- Generators at stations of >=5MW
  - Latest view of generator data is consistent with the initial view presented of £7.5m
  - For the purposes of this CBA, it would be prudent to assume a maximum cost of £10m

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# Cost of Implementation

- Generators at stations of <5MW
  - Number of sites
    - Up to 6GW of capacity
    - Includes over 1.5GW of solar
    - Excluding domestic solar, an average capacity per site of ~1MW would suggest ~4,000 sites
  - Loss of Mains Protection technique
    - Worst case assumption is that 50% use RoCoF
    - Domestic PV assumed to use proprietary protection techniques
  - General characteristics
    - Smaller, lighter synchronous machines
    - Limited use of voltage control capability
    - Simpler installations
  - Costs per site
    - A range of costs are plausible from a simple setting change to significant plant change
    - Assumed to be significantly less than replacing plant

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# Cost of Implementation

- Generators at stations of <5MW
  - Taking a view of different plausible scenarios

**Range Based on Different Site Number and Cost Assumptions**

| | High | Medium | Low |
|---|---|---|---|
| Max Number of Sites | 5000 | 4000 | 3000 |
| Proportion with RoCoF | 50% | 40% | 25% |
| Cost Per Site (£k) | 10 | 5 | 1 |
| **Sum (£m)** | **25.000** | **8.000** | **.750** |

**Hybrid Approach applied to 4,000 Sites**

| | Major Work | Complex | Simple | Total |
|---|---|---|---|---|
| Max Number of Sites | 250 | 1000 | 2750 | **4000** |
| Proportion with RoCoF | 50% | 50% | 50% | |
| Cost Per Site (£k) | 100 | 10 | 1 | |
| **Sum (£m)** | **12.500** | **5.000** | **1.375** | **18.875** |

- Highest value calculated is £27.5m
- £30m adopted as the plausible worst case for the purposes of this assessment

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# Projected Balancing Services Costs

- Costs for managing RoCoF constraints with a limit of 0.125Hzs$^{-1}$ have been calculated up to 2025/26
- Model uses 2012/13 generation data
  - Wind generation output has been disaggregated and scaled each year in accordance with the “Slow Progression” scenario
  - No demand growth
  - Excludes the effect of Solar PV

Baseline GB Wind Capacity In Scenario (MW)

| 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10,063 | 11,288 | 12,286 | 12,949 | 13,804 | 14,607 | 16,217 | 17,472 | 18,743 | 20,960 | 23,316 | 25,293 | 28,306 |

- Costs calculated for
  - Existing infeed loss risks
  - New infeed loss risks
  - A RoCoF limit of 1.0Hzs$^{-1}$
  - A RoCoF limit of 0.5Hzs$^{-1}$

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# Projected Balancing Services Costs

- Three views created, Best, Central and Worst
  - Best view assumes good trading capability, increasing synchronous plant flexibility and reduced wind generation output
  - Central view assumes average trading capability and increasing synchronous plant flexibility
  - Worst view assumes average trading capability, no development in plant flexibility, windier conditions and earlier connection of new infeed losses
- A weight of 30%, 60% and 10% has been applied to each
- Cost of Carbon has not been included

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# Projected Balancing Services Savings

## RoCoF Balancing Services Cost Projection Scenario Summary

**All Costs £m (2013/14 prices)**

| | | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Cost of Managing Existing Infeed Loss Risks | Best | 9.0 | 10.4 | 29.3 | 31.1 | 34.5 | 28.9 | 51.1 | 59.7 | 71.2 | 122.1 | 179.9 | 187.0 | 281.8 |
| | Central | 9.6 | 11.4 | 56.1 | 59.5 | 66.2 | 53.8 | 95.6 | 113.6 | 132.9 | 218.5 | 305.7 | 297.7 | 419.5 |
| | Worst | 10.4 | 12.4 | 60.8 | 65.4 | 72.9 | 81.2 | 151.6 | 182.0 | 224.2 | 500.1 | 730.5 | 959.3 | 1,391.7 |
| Total Cost Including New Infeed Loss Risks | Best | 9.0 | 10.4 | 29.3 | 31.1 | 149.8 | 146.1 | 182.3 | 328.4 | 483.7 | 580.7 | 814.6 | 841.2 | 966.0 |
| | Central | 9.6 | 11.4 | 56.1 | 59.5 | 184.2 | 294.6 | 364.9 | 390.2 | 557.3 | 692.4 | 962.4 | 975.1 | 1,130.9 |
| | Worst | 10.4 | 12.4 | 60.8 | 184.0 | 314.8 | 328.0 | 428.2 | 607.6 | 662.1 | 1,152.0 | 1,409.5 | 1,661.5 | 2,130.3 |
| Total Cost if Settings are Changed for >=5MW plant only | Best | 8.1 | 9.3 | 26.1 | 27.7 | 146.0 | 142.9 | 176.8 | 322.3 | 477.0 | 572.6 | 805.7 | 833.4 | 957.5 |
| | Central | 8.6 | 10.2 | 50.3 | 53.4 | 177.4 | 289.1 | 355.5 | 379.8 | 545.9 | 679.4 | 948.1 | 963.5 | 1,118.2 |
| | Worst | 9.4 | 11.2 | 55.0 | 177.8 | 307.9 | 320.2 | 415.3 | 593.2 | 646.3 | 1,130.3 | 1,385.7 | 1,636.2 | 2,102.7 |
| Total Cost of Limiting RoCoF to 0.5Hzs$^{-1}$ | Best | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 1.7 | 13.8 | 62.3 |
| | Central | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 1.1 | 17.6 | 49.0 | 170.0 |
| | Worst | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 11.6 | 51.1 | 118.5 | 376.9 |
| Scenario Weighting | Best | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | Central | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| | Worst | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

**All Costs £m (2013/14 prices)**

## Total Balancing Services Cost Summary

| | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Cost of Managing Existing Infeed Loss Risks | 9.5 | 11.2 | 48.5 | 51.6 | 57.3 | 49.1 | 87.8 | 104.2 | 123.5 | 217.8 | 310.4 | 330.6 | 475.4 |
| Total Cost Including New Infeed Loss Risks | 9.5 | 11.2 | 48.5 | 63.5 | 187.0 | 253.4 | 316.5 | 393.4 | 545.7 | 704.8 | 962.8 | 1,003.6 | 1,181.3 |
| Total Cost if Settings are Changed for <5MW plant only | 8.5 | 10.1 | 43.5 | 58.1 | 181.0 | 248.4 | 307.9 | 383.9 | 535.2 | 692.4 | 949.2 | 991.8 | 1,168.4 |
| Total Cost if Limit is set to 0.5Hz/s | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 1.8 | 16.2 | 45.4 | 158.4 |

| For info: | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baseline GB Wind Capacity In Scenario | 10,063 | 11,288 | 12,286 | 12,949 | 13,804 | 14,607 | 16,217 | 17,472 | 18,743 | 20,960 | 23,316 | 25,293 | 28,306 |

The cost of energy trading to reduce I/C imports, Priced at £20/MWh

The cost of energy to synchronise and create room for additional machines to provide inertia, priced at £150/MWh

The net annual cost accounting for occasions where trading is not possible

The cost of energy to synchronise and create room for additional machines to provide inertia to maintain a 660MW unit loss withstand, priced at £150/MWh

The cost of managing outages (eg busbar outages) including demand risks

Central Case

**Balancing Services Cost Projection (0.125Hzs$^{-1}$ Limit)**

| £m | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Infeed Loss Curtailment by Trade | 4.3 | 5.0 | 5.8 | 6.1 | 6.8 | 7.4 | 12.3 | 13.6 | 14.8 | 20.6 | 22.5 | 24.1 | 26.0 |
| Ability to Trade | 99% | 99% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% | 90% |
| Additional Syncs Alternative | 241.4 | 289.7 | 333.4 | 354.7 | 394.4 | 303.9 | 519.8 | 575.7 | 634.5 | 684.5 | 753.9 | 561.6 | 613.7 |
| Net Cost | 6.6 | 7.9 | 38.6 | 41.0 | 45.5 | 37.0 | 63.0 | 69.8 | 76.7 | 87.0 | 95.6 | 77.8 | 84.8 |
| Additional Syncs to meet Gen Unit Size Limi | .0 | .0 | .0 | .0 | .0 | .0 | 4.0 | 12.2 | 21.4 | 92.2 | 166.7 | 184.6 | 296.3 |
| Planned/Unplanned Contingencies | 3.0 | 3.6 | 17.5 | 18.5 | 20.6 | 16.8 | 28.5 | 31.6 | 34.7 | 39.4 | 43.3 | 35.2 | 38.4 |
| Total (Existing Infeed Risks) | 9.6 | 11.4 | 56.1 | 59.5 | 66.2 | 53.8 | 95.6 | 113.6 | 132.9 | 218.5 | 305.7 | 297.7 | 419.5 |
| Number of Larger Loss Risks | | | | | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 4 |
| Curtailment of Larger Loss | .0 | .0 | .0 | .0 | 118.1 | 240.8 | 269.4 | 276.6 | 424.4 | 473.9 | 656.7 | 677.5 | 711.4 |
| Additional Sync for Larger Loss | .0 | .0 | .0 | .0 | 3,623.7 | 4,945.5 | 5,376.6 | 5,489.1 | 8,359.4 | 6,769.3 | 9,375.9 | 6,433.2 | 6,721.0 |
| Total Including New Infeed Risks | 9.6 | 11.4 | 56.1 | 59.5 | 184.2 | 294.6 | 364.9 | 390.2 | 557.3 | 692.4 | 962.4 | 975.1 | 1,130.9 |

Action required on 135 nights, 30 days and 47 evenings at ~1.7GW per occasion

Action required on 166 nights, 44 days and 80 evenings at ~2GW per occasion

**Balancing Services Cost Projection (5MW and above only)**

| £m | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Planned/Unplanned Contingencies Saving | 1.0 | 1.2 | 5.8 | 6.1 | 6.8 | 5.5 | 9.4 | 10.4 | 11.5 | 13.0 | 14.3 | 11.6 | 12.7 |
| Total Cost | 8.6 | 10.2 | 50.3 | 53.4 | 177.4 | 289.1 | 355.5 | 379.8 | 545.9 | 679.4 | 948.1 | 963.5 | 1,118.2 |

**Balancing Services Cost Forecast (0.5Hzs$^{-1}$ Limit)**

| £m | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of Larger Baseload Loss Risks | | | | | | | | | 1 | 1 | 1 | 1 | 1 |
| Curtailment of Larger Loss (0.5) | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 1.1 | 17.6 | 49.0 | 170.0 |
| Additional Sync for Larger Loss (0.5) | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 1.8 | 10.3 | 14.7 | 42.9 |
| Net Cost | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 1.1 | 17.6 | 49.0 | 170.0 |

The cost of curtailing new larger losses priced at £150/MWh

The cost of energy to synchronise and create room for additional machines to provide inertia priced at £150/MWh (deemed uneconomic and disregarded)

The cost of curtailing new large baseload loss priced at £2,000/MWh

The cost of energy to synchronise and create room for additional machines to provide inertia priced at £150/MWh

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# Implementation Costs vs Savings

**All Costs £m (2013/14 prices)**

### Total Balancing Services Cost Summary

| | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Cost of Managing Existing Infeed Loss Risks | 9.5 | 11.2 | 48.5 | 51.6 | 57.3 | 49.1 | 87.8 | 104.2 | 123.5 | 217.8 | 310.4 | 330.6 | 475.4 |
| Total Cost Including New Infeed Loss Risks | 9.5 | 11.2 | 48.5 | 63.5 | 187.0 | 253.4 | 316.5 | 393.4 | 545.7 | 704.8 | 962.8 | 1,003.6 | 1,181.3 |
| Total Cost if Settings are Raised to 0.5Hzs$^{-1}$ or above for >=5MW plant only | 8.5 | 10.1 | 43.5 | 58.1 | 181.0 | 248.4 | 307.9 | 383.9 | 535.2 | 692.4 | 949.2 | 991.8 | 1,168.4 |
| Total Cost if Limit is set to 0.5Hzs$^{-1}$ | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | 1.8 | 16.2 | 45.4 | 158.4 |

### Total Achievable Savings

| | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cumulative Savings (1Hzs$^{-1}$): 2017 Completion | | | | | 187.0 | 440.4 | 756.8 | 1,150.2 | 1,695.9 | 2,400.8 | 3,363.5 | 4,367.1 | 5,548.5 |
| Cumulative Savings (1Hzs$^{-1}$ >=5MW only): 2016 Completion | | | | 5.3 | 11.2 | 16.3 | 24.9 | 34.4 | 44.8 | 57.2 | 70.9 | 82.7 | 95.6 |
| Opportunity lost for a setting change to 0.5Hzs$^{-1}$ compared to 1Hzs$^{-1}$ | | | | | .0 | .0 | .0 | .0 | .0 | 1.8 | 16.2 | 45.4 | 158.4 |

### Implementation Cost

| | | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 | 2018/19 | 2019/20 | 2020/21 | 2021/22 | 2022/23 | 2023/24 | 2024/25 | 2025/26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Generators at Stations of >=5MW | Cost | | 5.0 | 5.0 | | | | | | | | | | |
| | Cumulative Cost | | 5.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 | 10.0 |
| Generators at Stations of<5MW | Cost | | | 15.0 | 15.0 | | | | | | | | | |
| | Cumulative Cost | | .0 | 15.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 | 30.0 |
| Total | Cost | | 5.0 | 20.0 | 15.0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| | Cumulative Cost | | 5.0 | 25.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 | 40.0 |

- Points to note
  - Break even is achieved in the first year if settings are raised for all plant to 1.0Hzs$^{-1}$
  - Break even is achieved in 2 years if only plant >=5MW is modified
  - A lower setting makes a re-visit likely at which point the costs of making a change will be different

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# Conclusions

- The savings that can be achieved by changing RoCoF protection settings are large
  - £760m by 2020 according to the “central” cost case
  - £114m by 2020 with no new infeed risks under the “best” cost case
  - £1,000m by 2020 under the “worst” cost case
- The maximum estimated costs of implementing a change are significantly less at ~£40m
- A change for plant of >=5MW only, delivers savings which are big enough to offset costs but leaves significant costs to be incurred
- The 0.5Hzs$^{-1}$ limit becomes significant after 2020
  - Potential for transitional options for some plant
  - A general setting at this level would require a re-visit from 2017/18
- Working to a limit of 0.125Hzs$^{-1}$ on an enduring basis is not an option