NATIONAL GRID
ELECTRICITY TRANSMISSION

Harmonics Management workshop: summary feedback

Crowne Plaza Birmingham, 2 April 2019

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EXECUTIVE SUMMARY

- As the England and Wales Electricity Transmission network, we held a workshop on 2 April 2019 at the Crowne Plaza, Birmingham as part of our wider programme of stakeholder engagement.
- The aim of this workshop was to consult stakeholders on the proposed management of Harmonics Compliance as we prepare for the next regulatory period, RIIO-2, which begins in 2021
- 17 stakeholders representing 15 organisations attended the workshop, covering four of our main stakeholder segments

Headline summary

- There was a clear message from stakeholders that utilities should be responsible for managing Harmonic in the future.
- We should look to incentivise connectees through reasonable harmonic impact.
- We should recover costs through the base transmission revenue.

1. CONTEXT

Almost all connectees with voltage distorting equipment (e.g. windfarms, HVDC link) undertake harmonic assessments and build harmonic filters to comply with Grid Code requirements. Compliance with harmonics levels helps us to meet the stakeholder priority of providing a safe and reliable network.

The current approach in managing harmonics in Great Britain is that the connectee is responsible for cleaning or minimising the distortion they create. However, the electricity market is rapidly changing in terms of the technology connecting to the transmission and distribution networks. Over the past few years, there has been a significant increase in the penetration of harmonic emitting plants (such as wind farms, interconnectors, batteries, traction loads, PVs etc.), and this is only set to increase in future with the anticipated take-up of electric vehicles and the associated requirement for charging points.

In addition, changes in the types of plant mean that system short circuit levels are reduced, the network becomes weaker and there is an increase in background harmonics. This increase cannot be attributed to any individual connectee.

All of this means that a rethink is required in the way harmonic compliance is managed. Our day to day system design activities have shown that installation of these filters by connectees could be inefficient and potentially not in the best interests of consumers, due to the increased number of filters required for these 'connectee side' installations and the inability for connectees to consider future network changes and impacts on the harmonic levels at the time of connection.

Our studies have shown that a more efficient approach could be for us to install these filters on our network. This would allow us to base installation decisions on an overview of the wider network and not just individual connection requirements, and would potentially reduce the overall number of filters required (and therefore the overall cost to consumers). It would also mean that filter installation costs are shared more fairly across all connectees.

2. OBJECTIVES AND FORMAT

Engagement approach and targeted stakeholder

We began by talking to the other transmission and distribution networks to understand their views on examining options for a new approach, on the basis that taking anything new forward would be unlikely without their support. This was done in a series of face to face meetings between technical experts from the respective companies.

Following this, we held a broader workshop to discuss issues and options in more detail. We invited representatives of stakeholders with an existing or potential future interest in this topic. A workshop was chosen as it's a channel which allows for face to face sharing of information and two-way discussion, and Birmingham was chosen as a central location with good transport links.

Through our engagement activities, we are looking for stakeholder views on their preferred approach to the future installation of harmonic filters in RIIO-T2. We would like to explore other options that can achieve harmonic compliance in the network in a much more coordinated, efficient and economical manner than each individual connectee having to build their own filters.

In parallel to this engagement, we are also working with a specialist third party to understand the likely technical implications of installing filters on our network, from which we will be able to provide cost comparisons. Our stakeholders' views, along with this cost analysis, will provide evidence to support the most technically suitable and efficient solution.

We structured the day around topic-specific sessions. For each session, this involved:

- a short presentation to provide enough context for all stakeholders to be able to discuss the subject area followed by question and answer session.
- Three sessions had voting options and stakeholders were asked to either rank or vote on their preferred options.

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3. WORKSHOP ATTENDEES

The following organisations were represented at the workshops, with 17 attendees in total:

ABB	Network Rail
Atkins Global	NIE Networks
Enotrac	PSC Consulting
ESB	StatKraft
National Grid Ventures	SP Energy Network
National Grid ESO	TNEI
National Grid	UK Power Networks

Segmenting our stakeholders

We asked attendees to classify themselves into stakeholder segments, as shown below.

Note:

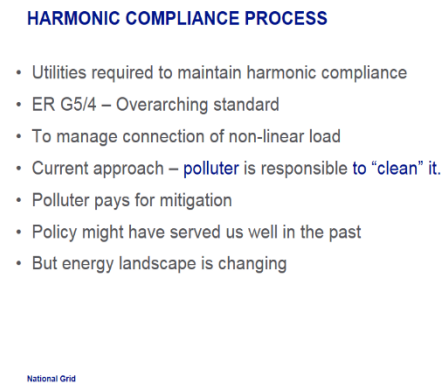
Stakeholder group	**Attendees**
Energy network owner or operator	9
Other non-energy industry	2
Supply chain	2
Interest organisation/ Consultants	1
Regulator or government	0
Consumer interest organisation	0
Other energy industry	0
University, think tank or academic	0

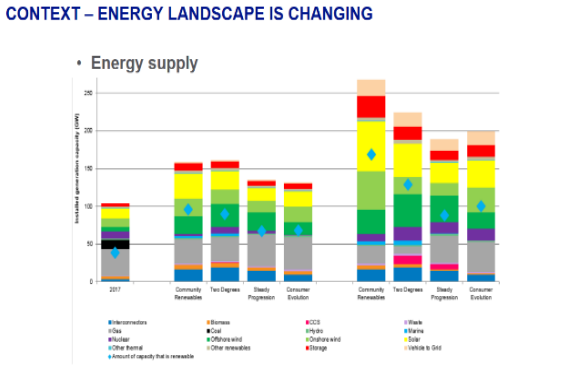
4. STAKEHOLDER FEEDBACK

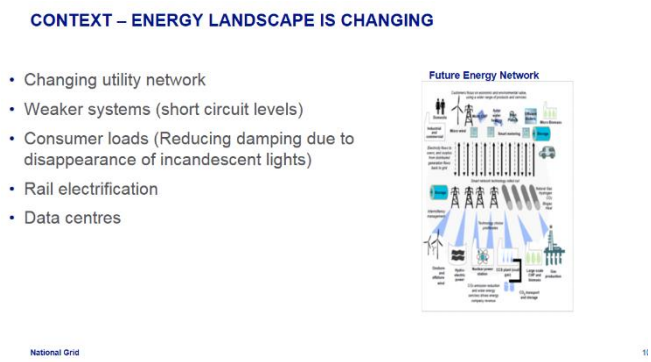
This section provides a summary of the feedback received, taking each workshop session in turn.

4.1 Session 1: Harmionics Compliance Process

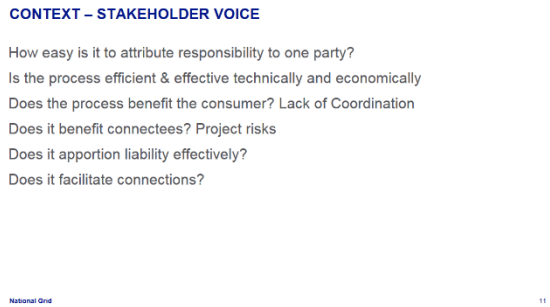
We began the workshop with an overview of the current harmonic compliance process and that utilities are required to maintain harmonic compliance and that ER G5/4 is the overarching standard for this. We explained that the current approach is that the polluter is responsible to clean it up and pays for mitigation. The current policy has been the correct one however we then explained the changing energy landscape and how this now means the policy need to change.

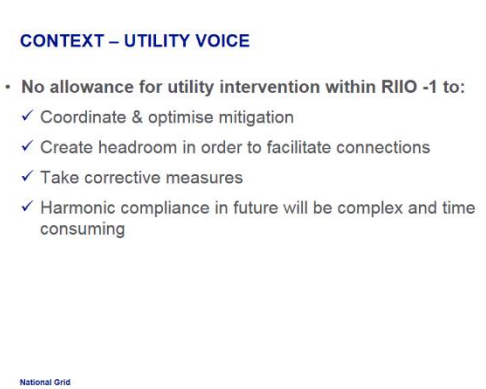






We then discussed the voice of the stakeholder, how easy it is to attibute responsibility to one party and whether the process is efficient and effective and benefit the consumer.





We explained that under RIIO-1 we currently do not have an allowance for interventions. Which means that there is no coordination. No headroom is created to facilitate connections and take corrective measures and that going into RIIO-2, Harmonics will be more complex and time consuming.

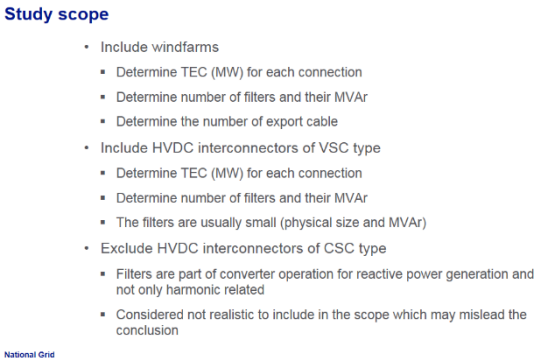
We explained the objectives of the Harmonic review and that it was a way of managing harmonic compliance in a way that is coordinated and optimised. That it would facilitate connections and decarbonisation, improve effectiveness and efficiency of the process and simplify the harmonics process.

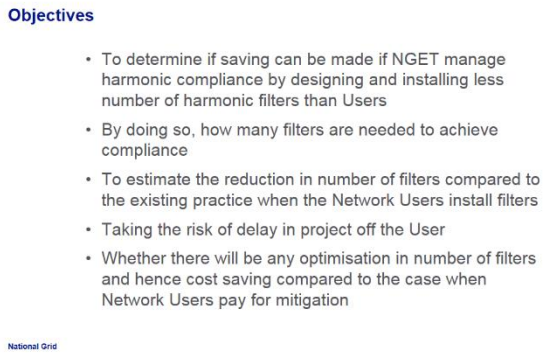
We explained that the workshop was to seek views and feedback from stakeholders.

4.2 Session 2: Technical Analysis carried out by National Grid

The next part of the workshop was explaining to stakeholders the case studies carried out by National Grid. The objectives of the study were explained. as well as what was in scope from a National Grid perspective.

The approach taken was explained and that we have analysed the data from the past looking at how many harmonic filters have been installed by network users, how much MVAr is generated by the filters and then determined a parameter that relates to the number of filters connected. We also considered the future, collecting data from future connections and used this to determine the number of filters to be connected.





We explained the methodology of the study was to follow a sequential connection approach to be based on year of connection and study the impact on harmonic distortion for each connection then develop the appropriate filter solution and compare against the performance of the filter installed by the OFTO(s). To evaluate performance, we compared the resultant amplification due to National Grid designed filters and that of existing OFTO filters, this was deemed the most pragmatic approach.

We shared the 3 case studies, and the regions considered being, a concentration of wind connections with harmoinc filters in the north west, a large numer of wind farm connections in the east and future connections in the south east and east. We shared the detail anaylsis and information.

We shared our conclusions of the study. The study showed that if NGET managed harmonic mitigation in the past 54.2% and 31.3% less filters would have been installed respectivaly with redundancy. The historical data was used to determine the estimating factors to estimate how many filters will be used by the future connections if users and also NGET were to manage user impact. The results showed that at least a reduction of 36.8% in the numer of filters can be achieved for a 8-year period from 2021 to 2029.

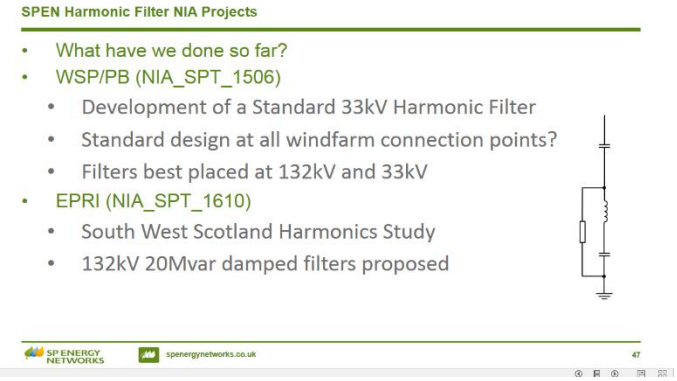
Summary of stakeholder comments and questions:

There were some questions and comments about the technical analysis.

- The consensus was that the approach was good but need to consider the newer generation of VSC HVDC, i.e. MMC type but agree with assumptions made by NGET for filters (size and numbers) required for VSC connections
- Several stakeholders voiced that the current Harmonic process was the risk to the projects rather than actual requirements to design and install the filters and that the current process was the blocker causing delays to tendering process.
- Stakeholders were keen to know how compliance would be ensured.
- Stakeholders were keen to understand the cost saving.

4.3 Session 3: Technical Analysis carried out by Scottish Power Energy Network.

The next part of the workshop was explaining to stakeholders the case studies carried out by Scottish Power Network. The objectives of the study was explained, as well as what was in scope from a Scottish Power Energy Network.



It was explained what SPEN had done to date in terms of designing standard filters and its application to the future South West network.

SPEN explained the resonant issues due to a combination of a radial network and wind farm cabling. It was explained that a coordinated mitigation solution at 132kV level by the Utility was more effective both technically and economically. . The session concluded with SPEN explaining that the TO solution was more economic and efficient, that users have a responsibility and that the polluter should continue to pay.

Summary of stakeholder comments and questions:

There were some questions and comments about the technical analysis from SPEN.

- Stakeholders wanted to know how will this be applied to the existing connections retrospectively.
- As well as how the mess made by users are defined.
- A comment on Installing better VTs and monitoring equipment would be useful to better manage harmonics in first place was made.

4.4 Session 4: Harmonic Compliance International approaches

In the next session, PSC Consulting explained how Harmonics Compliance was managed internationally.

The sessions focussed on EirGrid in Ireland, Engerginet in Denmark and TenneT in the Netherlands as well as other networks.

EirGrid/Energinet/Tennet/TasNetworks

- IEC 61000-3-6 (but considering background) (slight mods in AUS)
- Calculate limits for a new connectee
- Use of available headroom – (maintain some margin for future)
- Consider N-1 contingencies and remote nodes
- Multiple connections → share of headroom
- Limits and impedance data provided
- Mitigation by connectee if required and provide compliance report
- Single connectee → Infrastructure change → amplification issue → utility specifies mitigation for the transmission system → cost passed to the connectee (EirGrid)
- Temporary acceptance until measurements over 3 months confirm (Energinet)
- Responsibility of background amplification is on the TSO (TenneT)

RTE/Manitoba Hydro/Hydro Quebec

- Harmonic current limits derived wrt IEC 61000-3-6 and/or IEEE519
- Diverse approaches
- All trying to limit overall system level
- CART levels higher than IEC 61000-3-6 used by RTE
- Not much experience so far with limits being an issue to comply with

ONS (Brazil)

- ONS grid code and technical specs
- Individual (at PCC for individual customers) and Global limits (to verify whole system performance) all fixed
- Global limits have a band, connections classed as "under observation" if distortion is within the band
- Global limit non-compliance triggers investigation → TSO or customer responsibility
- Customer impact evaluated at planning stage and customer is responsible for designing mitigation measures
- System data provided for mitigation measure design
- Temporary acceptance employed

The table belowshows who has the responsibility of managing compliance and paying in each country.

Responsibility for Paying

Country	Who Mitigates / Who Pays		
	Passive Amplification		Active Injection
	Network Development	Connectee's System	
Ireland (EirGrid)	New Connectee	New Connectee	New Connectee
Denmark (Energinet)	Socialised	New Connectee	New Connectee
Netherlands (TenneT)	Socialised	Socialised	New Connectee

Summary of stakeholder comments and questions:

- It was noted that in TenneT case, they build the network out to OFW rather OFTO as in UK, that is why they manage the harmonic mitigation.
- Hydro Quebec / Manitoba have large HVDC links integrated centrally within their network providing damping so they don't have much harmonic issues in their network.
- Late development model is used in the UK.
- It was asked who is responsible for conducting analysis in different countries
- Are there obligation / regulatory requirements for Utilities to bring the cost down overall in different countries?

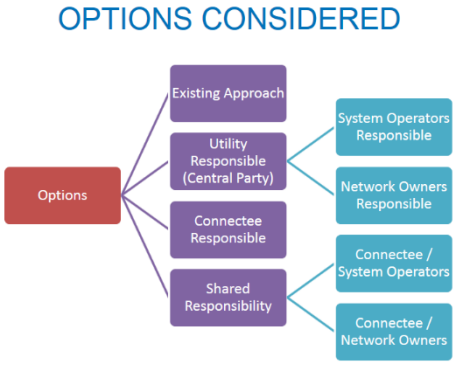
- Are the remote nodes considered only in the UK?

4.5 Session 5: Harmonic Compliance management alternative UK Model.

In the next session, PSC Consulting explained an alternative UK model for Harmonic Compliance.

PSC explained that there was an opportunity for more effective approach and that the existing system does not account for increased in general harmonic consumer distortion. There is a constantly changing system/harmonic background which may introduce delays in the connection process. Some of the harmonic issues may be resolved or not materialise due to future system development and that the existing approach makes both utility and customer responsible.

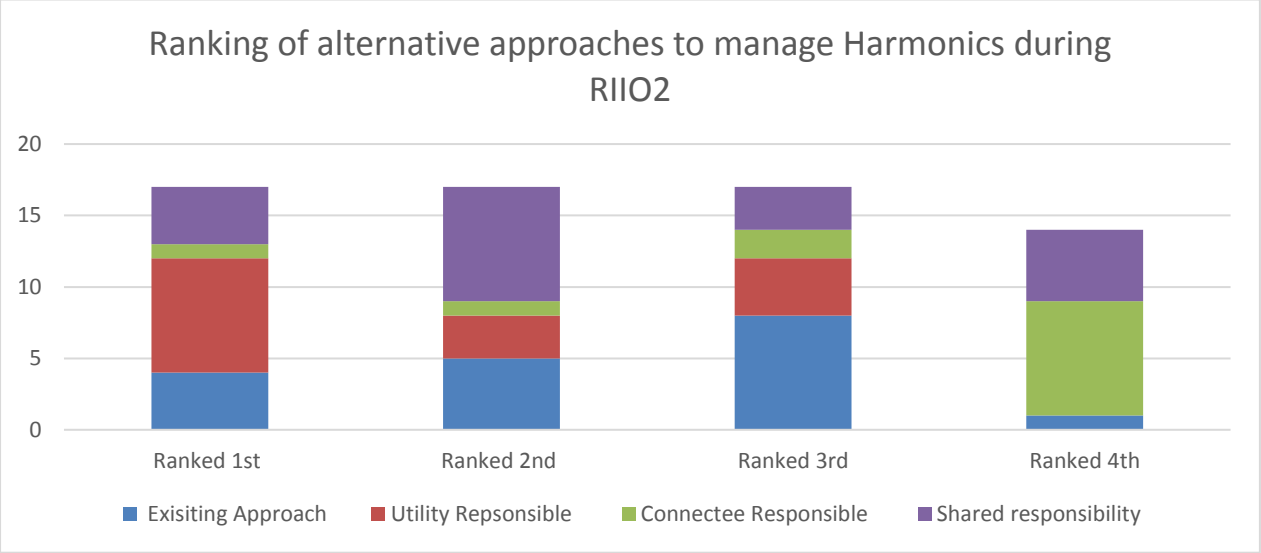
PSC explained the options they had considered as well as benefits/opportunities and risk and challenges.



COMPARISON

Activity	Utility Responsible	Connectee Responsible	Shared Responsibility
Existing System Measurements	Utility	Connectee	Utility
System Modelling and Studies	Utility	Connectee	Utility
Mitigation Specification	Utility	Connectee	Utility
Mitigation Responsibility	Utility	Connectee(s)	Connectee(s)
Monitoring	Utility	Connectee	Connectee

The session was summarised by the alternative approaches to responsibility for harmonic distortion management, the utility is responsible, connectee responsible, share responsibility or stay as is. Stakeholders were asked to rank their preferences which the results are shown below:



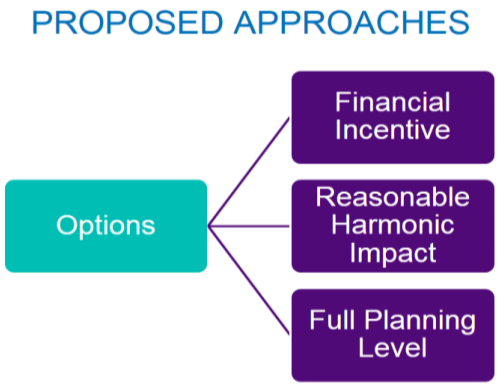
Most stakeholders ranked the utility responsible as their first preference.

Summary of stakeholder comments and questions:

- Responsibility for harmonic compliance assessment seems to be done better centrally. Some other things like voltage performance needs to be managed properly
- Connectee responsible is too complex to implement
- If connectee responsible need data from NG. this should be publicly available and updated regularly.
- No to connectee responsible, the connectee does not have the system knowledge of the TO to be responsible for defining the requirements.
- Some design co-operation would be nice though e.g. to account for customer energisation sequence or switching arrangements if they have a large cable network.
- For whole responsibility on the User option, there is issue about who owns which data. NG will own majority of the data and if the User is responsible to carry out analysis how will data sharing happen given the confidentiality agreements.

4.6 Session 6: Harmonic Compliance incentivising connectees

The next session PSC explained incentivising connectees to consider their harmonic impact. PSC shared three proposals highlighted below:



COMPARISON

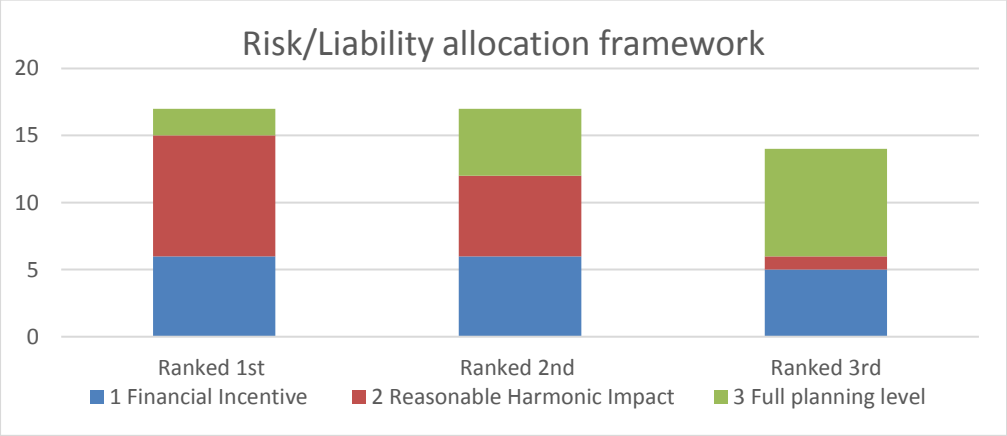
Activity	Financial Incentive	Reasonable Harmonic Impact	Full Planning Level
Connectee System Data Upfront	Detailed	General	None
Connectee Harmonic Impact	No Restriction	Technology Based	Full Planning Level
Existing Background	Considered	Considered	Not Considered
Connectee Mitigation	None	Potentially	Unlikely
Connectee Fee	Proportional	Proportional	None

Each one was discussed in turn and then comparison made for each one. Benefits and risks of each where then discussed.

In summary connectee fee incentivises them to reduce their harmonic impact but the charging mechanism will be very complex.

Socialising all costs is simpler but does not incentivise the connectee to consider their contribution.

Stakeholders were then asked to rank their preference on the risk/liability framework. Majority of stakeholders ranked *Reasonable Harmonic Impact* as their first option.



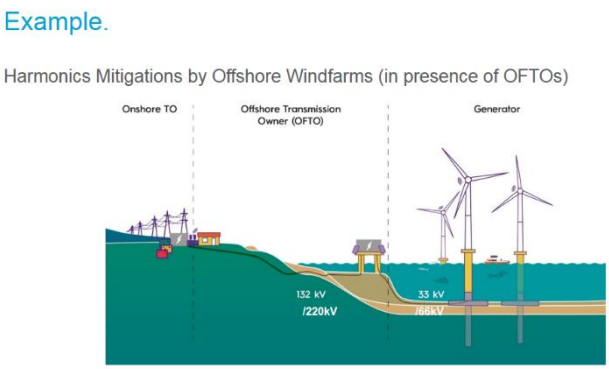
Summary of stakeholder comments and questions:

- Number 2 would seem to offer a reasonable risk/reward.
- Number 3 is too complicated
- Reasonable harmonic impact is too open to interpretation.
  Financial incentive needs to consider how the fee structure works and split between connected/system users
- Need to have a very robust and transparent charging mechanism for option 1 to be viable
- Both user and utility need to share. Is a financial incentive too complicated?
- Rather than creating headroom,you should consider benefits to system and impact on equipment by reducing harmonic pollution on the network.
- Impact of harmonics on the expected design life expectancy and degradation of the equipment also needs to be considered.
- TOs are responsible to plan and design a network that is operable.

4.7 Session 6: Existing cost recovery methods for harmonic mitigation.

In the next session, AtkinsGlobal discussed the existing cost recovery methods for harmonic mitigation.

Atkins Global explained the example the generators builds the OFTO assets.
The assets are transferred through to an OFTO through a tender process carried out by Ofgem. The asset value is determined by Ofgem following benchmarking as part of a Final Transfer Value (FTV).



FTV and O&M translates (including RPI, WACC, RoR) to a tender revenue stream Collected on behalf of the OFTO through the TNUoS – the local substation element of the generation tariff and charged to the windfarm owner/developer.

We then explained harmonic mitigations in Offshore Transmission System and how the Harmonic filter will form part of the OFTO assets.

We then discussed how the Transmission Network Use of System (TNUoS) - recovers the maximum allowed revenue.

The session was then summarised by compliance with ER G5/4 in offshore transmission system and the development stage sits with the developer. Following the transfer of the OFTO assets, compliance with G5/4 is the responsibility of the OFTO (through normal maintenance of the harmonic filters). Any Harmonic Filter installation by the developer to mitigate the increased harmonic levels is charged back to the generator (i.e. developer) through TNUoS charges (local substation charge).

The developers are still paying for wider charges (charges which reflect maintenance of the onshore transmission systems) which are determined through CUSC .

4.8 Session 7: Impact of proposed approach on different stakeholders

The next session focussed on the impact of proposed approach on different stakeholders.

Two options were discussed and then the options compared and summarised.

Option 1: Cost recovery by changes to the base transmission revenue

- Pre-defined projects with specific milestones or,
- A pre-defined revenue driver, with output targets such as £/MVA, £/MVAr, £/MW headroom of generation connection facilitated
- Recovered from the maximum allowed revenue, translates into a higher TNUoS – specifically the wider generation tariff

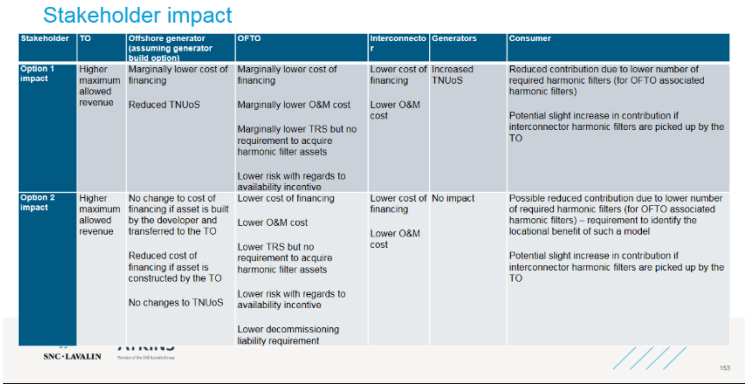
Option 2 – Cost recovery based on connection charges

Variant 1:

- *Identified and installed assets as part of individual connections constructed by NGET*
- *Recovered through a new set of connection charges to the developer within BCA*

Variant 2:

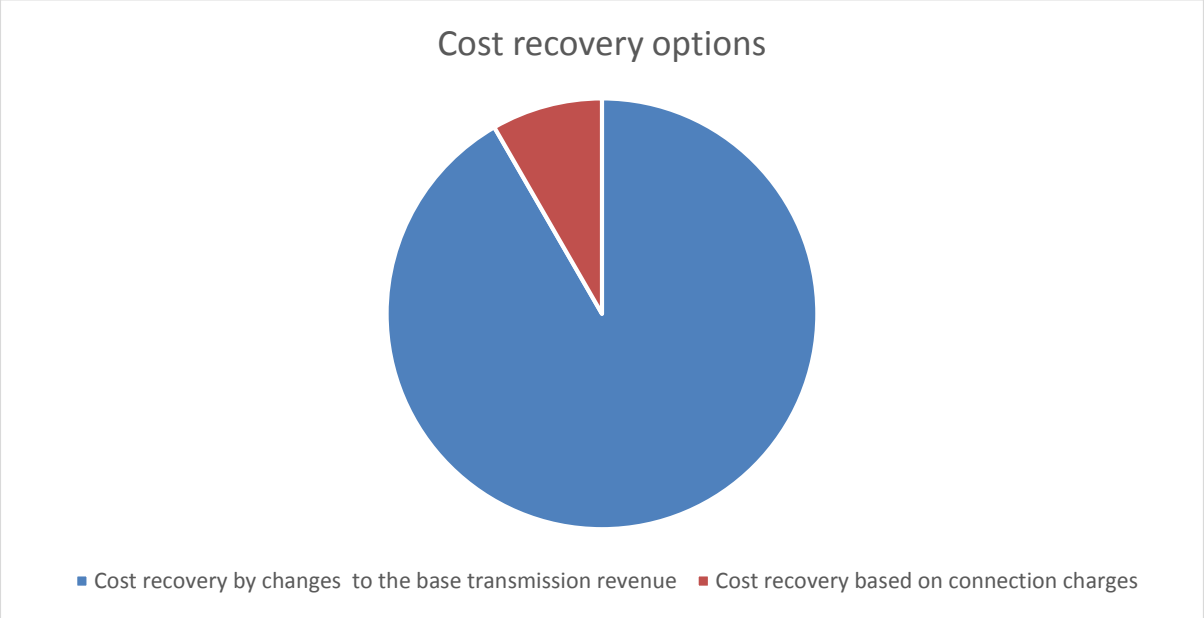
- *A project developer following identification of the requirements as part of the CION process build the asset and hand over to the onshore TO instead of the OFTO. TO pays for these assets (similar to an FTV paid by the OFTO) and the costs being then recovered by the TO through annual connection charges*
- The locational benefit of centralized ownership may be lost
- Unclear how a parallel process of asset transfer for one part of the OFTO process will be implemented


Stakeholder impact

Stakeholder	TO	Offshore generator (assuming generator build option)	OFTO	Interconnector	Generators	Consumer
Option 1 impact	Higher maximum allowed revenue	Marginally lower cost of financing Reduced TNUoS	Marginally lower cost of financing Marginally lower O&M cost Marginally lower TRS but no requirement to acquire harmonic filter assets Lower risk with regards to availability incentive	Lower cost of financing Lower O&M cost	Increased TNUoS	Reduced contribution due to lower number of required harmonic filters (for OFTO associated harmonic filters) Potential slight increase in contribution if interconnector harmonic filters are picked up by the TO
Option 2 impact	Higher maximum allowed revenue	No change to cost of financing if asset is built by the developer and transferred to the TO Reduced cost of financing if asset is constructed by the TO No changes to TNUoS	Lower cost of financing Lower O&M cost Lower TRS but no requirement to acquire harmonic filter assets Lower risk with regards to availability incentive Lower decommissioning liability requirement	Lower cost of financing Lower O&M cost	No impact	Possible reduced contribution due to lower number of required harmonic filters (for OFTO associated harmonic filters) – requirement to identify the locational benefit of such a model Potential slight increase in contribution if interconnector harmonic filters are picked up by the TO

Stakeholders were then asked to vote on their preferred option.

The results were as follows:



Option one was the preferred option.

Summary of stakeholder comments and questions:

- If the transmission owner builds the asset not only for a specific customer, the costs should be socialised.
- Connection charges will be very complex with multiple new connectee, particularly once you consider large numbers of smaller connections.
- Charges to the transmission revenue will need to take into consideration some method to scrutinize the requirements for passive filters vs alternative approaches.
- Recovery based on connection does not deliver efficiencies. Major risk for developed building assets in third party (TO) location

5. NEXT STEPS

We would like workshop attendees to confirm whether we have correctly captured and interpreted the feedback provided. Any comments should be provided to our Stakeholder Manager, Julie Cook, at Julie.cook@nationalgrid.com

If we have not already done so, we will answer specific questions raised at the workshop with a direct response to attendees.

THANK YOU

Thanks again to all who have contributed so far. If you have any questions, would like to suggest additional topics for engagement, or would like to get involved in further engagement activities, please email Julie.cook@nationalgrid.com