6

ESO process for High Voltage and Stability Management

High voltage and stability management are two separate processes with different technical assessments. However, they share a number of similarities in the economic assessment and tender processes and have therefore been combined into one section.

Overview of the High Voltage and Stability Management Process

6.1 The objective of the process is to ensure economical and efficient options for high voltage and stability management will be available when required. This Electricity System Operator (ESO) led process is designed to identify high voltage and stability issues in the transmission system, the causes, requirements and the preferred options to solve these issues. The process is designed to work with all expected option providers including Transmission Owners (TO), Distribution Network Owners (DNO) and Commercial Service Providers. *Figure 6.1* gives an overview of the high voltage and stability management process.

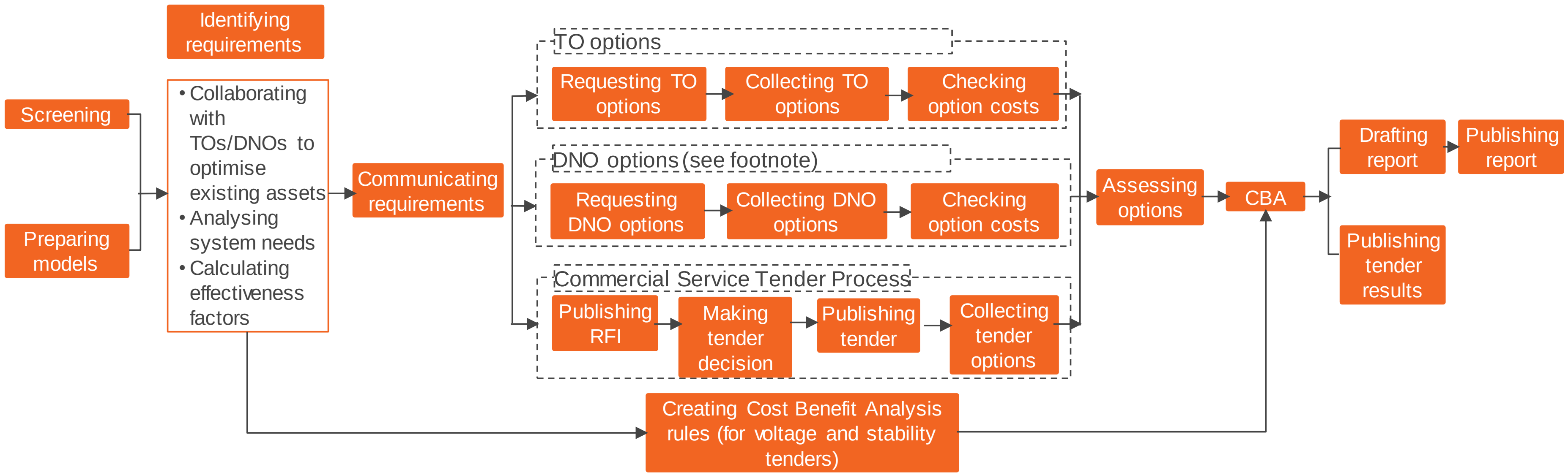

Figure 6. 1Overview of the high voltage and stability management process[23]

[23] In the long term when a regulatory funding mechanism for DNO options is agreed, it is expected that DNO options will follow a similar route as TO options, but presently a suitable regulatory funding mechanism is not in place for the DNO options. Until a suitable funding mechanism is established it is expected

Programme

6.2 The ESO carries out the screening process annually. The ESO anticipates to carry out the screening process after the annual technical analysis of boundary capabilities for ETYS & NOA.

6.3 Detailed assessment of any prioritised regions will be initiated on demand and as agreed between the ESO and the relevant TOs and DNOs.

6.4 Timeline of the detailed assessment of any prioritised regions will vary depending on the complexity and the size of requirements. The ESO will agree the timeline with the relevant TOs and DNOs involved.

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that the DNO options will be paid via the Balancing Service Contract; hence DNO options will follow the same route as Commercial Service options in the short term. The stability solutions are expected to be more effective at the higher voltage levels due to network impedance and therefore the DNO options may not be applicable.

Roles and responsibilities

System Operator

6.5 National Grid Electricity System Operator (ESO) leads the high voltage and stability management processes. ESO shall be responsible for:

- Plan develop and operate the NETS in accordance with the SQSS
- Selecting and prioritising regions by screening
- Preparing network models for analysis
- Collaborating with TOs and DNOs to identify requirements
- Communicating requirements to providers
- Collecting options from providers
- Assessing options
- Collaborating with DSO[24] to carry out the technical assessment of distribution-connected options
- Recommending options based on cost-benefit analysis
- Communicating process conclusions to providers
- Procuring Commercial Power Services via Balancing Service Contract
- Publishing the high voltage and stability management process Reports.

Transmission Owners

6.6 Transmission Owners (TO) shall be responsible for:

- Plan and develop their networks in accordance with the SQSS
- Providing feedback on regions which they think should be prioritised in this process
- Preparing network models for analysis
- Collaborating with ESO to explore options from existing assets of their networks for analysis
- Collaborating with ESO to identify requirements
- Supporting the assessment of options which could have an impact on their network
- Proposing options using the System Requirement Form – Voltage/Stability.

Distribution Network Owners

6.7 Distribution Network Owners (DNO) shall be responsible for:

- Compliance of their networks
- Preparing network models for analysis
- Collaborating with ESO to explore options from existing assets of their networks for analysis.

DNOs shall also be responsible for the following, while the relevant DSO does not yet exist:

- Collaborating with ESO to identify requirements
- Supporting the calculation of effectiveness factors for their networks
- Collaborating with ESO to carry out the technical assessment of distribution-connected options which connect to their networks.

DNOs will be invited to respond to any Request for Information and/or participate in any Tender Process. They can propose options which meet requirements set out by ESO via the Tender Process[25].

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[24] Where a relevant DSO function does not yet exist, it is expected that the relevant DNO will take responsibility.

[25] In the long term when a regulatory funding mechanism for DNO options is agreed, it is expected that DNO options will follow a similar route as TO options, but presently a suitable regulatory funding mechanism is not in place for the DNO options.

Reactive Power and Stability Commercial Service Providers

6.8 Reactive Power and Stability Commercial Service Providers will be invited to respond to any Request for Information and/or participate in any Tender Process. They can propose options which meet requirements set out by ESO via the Tender Process.

Principle of assessment for high voltage and stability issues related investment

6.9 The ESO plans, develops and operates the transmission system so that voltage and frequency levels stay within the normal operating ranges defined within the National Electricity Transmission System Security and Quality of Supply Standards (NETS SQSS)[26]. The specific voltage and frequency limits used in planning and operating the transmission system can be found in chapter 6 of the NETS SQSS.

6.10 To ensure the ESO can plan the system to operate securely and safely while managing voltages and system stability both economically and efficiently, a Network Options Assessment (NOA) style methodology is proposed. This will facilitate the assessment of options to develop the electricity networks to meet future voltage and stability control requirements.

High Voltage Assessment

6.11 In terms of voltage control requirement, an immediate need is being seen for high voltage control, so the initial focus will purely be on managing high voltages. This will be an expansion to the existing NOA methodology which primarily focuses on thermal and low voltage issues that are typically seen when power transfer across the network is high. This is normally assessed at peak demand periods. High voltage issues are typically encountered during period of light system loading or minimum demand.

6.12 Other voltage control concerns are present but to avoid increased complexity and delay they are not being addressed in this methodology. As the NOA methodology continues to evolve, the ESO will expand the methodology to cover further voltage control concerns in the future.

6.13 High voltage issues are typically confined to relatively small areas and voltage control solutions are usually ineffective over long distances so the ESO will apply a regional approach to the assessment.

6.14 The ESO uses cost-benefit analysis (CBA) to provide investment recommendations. Cost-benefit analysis compares the cost of a proposed solution and the monetised benefits over the project's life to inform the investment recommendation. To effectively meet the future voltage control requirement, the ESO also considers system operability when recommendations are made. The two primary factors that will drive an ESO recommendation are:

a. **Monetised benefits**, when monetised benefits are higher than the forecast solution cost. This implies investing in the proposed solution will provide a more economical and efficient way to manage voltages in the long term when compared to the ESO paying for reactive power service in real-time via the Balancing Mechanism (BM).

   <u>Justification based on monetised benefits</u>

   The monetised benefits are the cost saving achieved by investing in a proposed solution compared to using existing services such as Obligatory Reactive Power Services (ORPS)[27]. The ESO currently relies heavily on the reactive power capabilities of generators for managing voltage. The ESO hopes to see savings on constraint cost and, in some cases, utilisation cost as well. To estimate this saving, the ESO forecasts the constraint and utilisation costs they will pay for accessing and using the ORPS via the BM.

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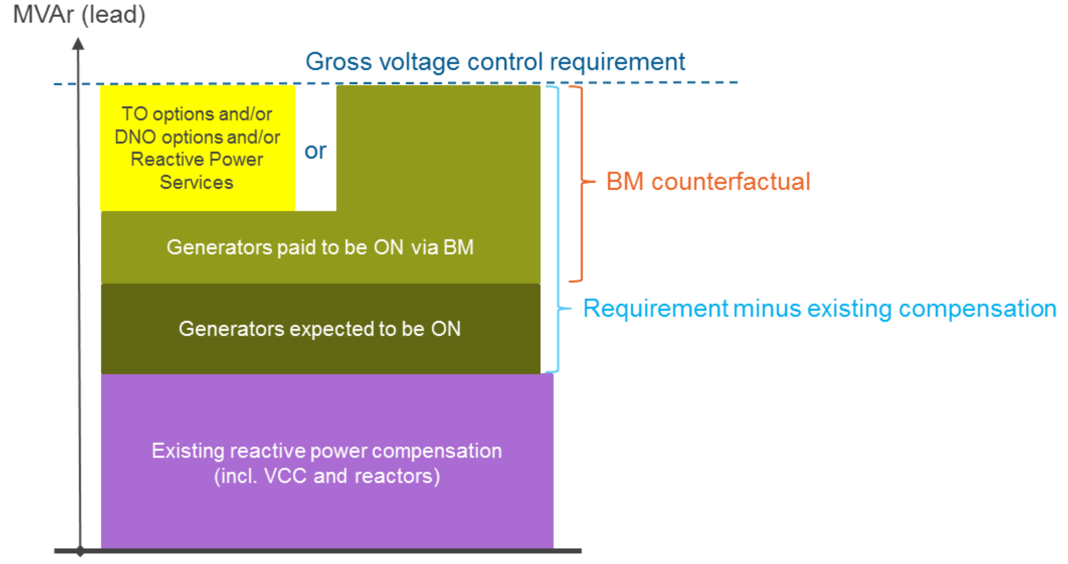
[26] Transmission Licence Standard Conditions C17: Transmission system security standard and quality of service, Paragraph 1

[27] The Obligatory Reactive Power Service(ORPS) is the provision of varying reactive power output. At any given output generators may be requested to produce or absorb reactive power to help manage system voltages close to its point of connection. All generators covered by the requirements of the Grid Code are required to have the capability to provide reactive power.

Constraint cost refers to the bid and offer price the ESO pays (for the MW) to get a generator onto the system to provide reactive power support, together with another generator reducing its generation or turned off elsewhere on the system to maintain the balance of supply and demand. Utilisation cost refers to the payment the ESO makes (for the MVAr) to generators for using their reactive power capabilities, the more being used the higher the cost.

The aim here is to find the solutions which deliver additional benefits to the consumers, in the form of net savings. This is achieved by replacing services which will need to be procured via the BM with lower cost proposed options. *Figure 6.2* shows how proposed options replace services from the BM to meet the voltage control requirement. The ESO uses cost-benefit analysis (CBA) to compare forecast investment costs and monetised benefits over the duration of the system need to inform this investment recommendation.



In this case, the ESO expects the remaining requirement (i.e. gross requirement minus existing compensation) can be satisfied by generators with mandatory service agreements (MSA) (or other contractual obligations).

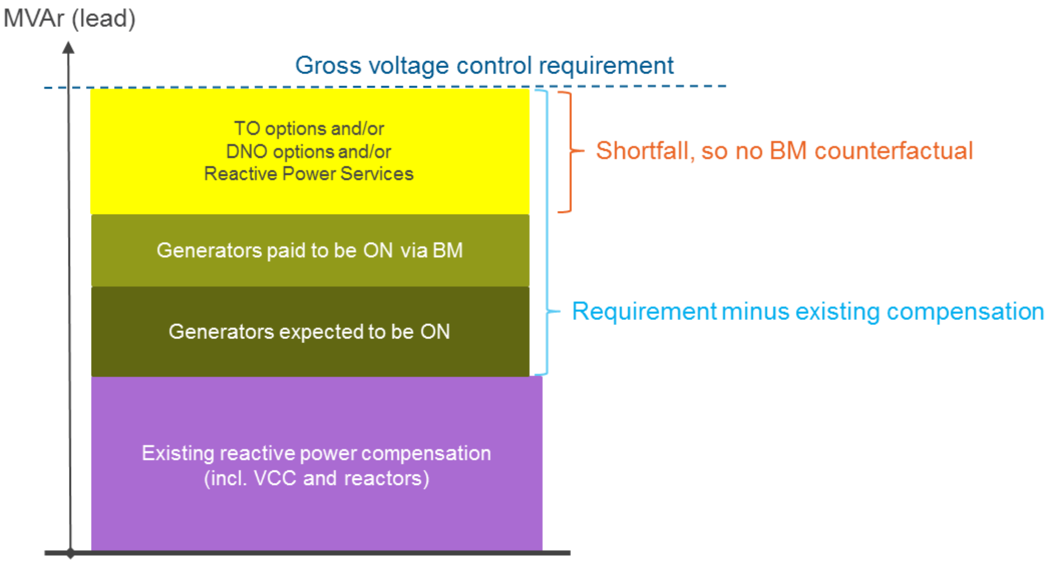
Investment recommendations made in this case focuses on the monetised benefits. It is possible for the ESO to secure Reactive Power services in real-time via the BM and ORPS. The aim is to explore potential solutions which provide overall savings to the consumers.

Figure 6. 2 Proposed options replacing services from the BM to meet voltage control requirement

b. Operational security requirement, when there are insufficient means to provide reactive power to contain high voltages and securely operate the network. This implies the forecast reactive power required in the future is higher than is forecast to be available via the BM or other means.

Justification based on security and operability

Given the rapid changes in generation and demand backgrounds, there may be times in the future where there will be insufficient reactive power compensation or services available to meet the voltage control requirements within a region. If such situation is observed in the analysis, the ESO will then focus on verifying the credibility of the assumptions leading to such a situation. If deemed credible, the most cost effective solution to resolve the situation will be pursued. *Figure 6.3* shows how proposed options provide the reactive power needed to meet voltage control requirement as sufficient services cannot be procured from the BM.



In this case, the ESO expects to have insufficient reactive power capability available and cannot satisfy the requirement by using generators with MSAs.

Investment recommendations made in this case focus on the operational security requirement. There is a risk that the system will be inoperable in real-time if nothing is available to provide the extra reactive power required to control the high voltages.

In order to meet the requirement (indicated as shortfall in the diagram), this may also mean that if generators who have MSAs wish to propose a l reactive power service option, the ESO can only consider it if they are offering reactive power capability above their mandatory requirements in the tender process.

Figure 6. 3 Proposed options providing the reactive power needed to meet voltage control requirement as sufficient services cannot be procured from the BM

Stability **Assessment**

6.15 Voltage and frequency limits used in planning and operating of the transmission system are stated in the NETS SQSS. The GB Grid code defines performance requirements for different users connected the National Electricity System for different system conditions (e.g. fault ride through requirements, voltage and frequency withstand variations).

6.16 The ESO considers stability at national level where solutions' ability to provide stability support is independent of its electrical location. The ESO also considers stability on a regional basis where both the need and the solutions are location specific. There will be some interaction between these two types of needs that the ESO will manage in communicating the requirements.

- At a national level, ESO maintains system frequency within limits by consideration of frequency response/reserve market products and maintains Rate of Change of Frequency (RoCoF) within limits by consideration of largest generation/demand loss on the system and planning for national levels of inertia.
- At a regional level, the distribution of regional inertia, short circuit level, dynamic voltage support can influence the stability of the local network and its users.

6.17 Similar to Voltage assessment, in order to ensure the system is planned in a way that it could be operated securely and safely while system stability is managed both economically and efficiently, a Network Options Assessment (NOA) style methodology is proposed. This will facilitate the assessment of options to develop the electricity networks to meet future stability requirements.

6.18 The ESO uses a cost-benefit analysis (CBA) to provide investment recommendations. The cost-benefit analysis compares the cost of a proposed solution and the monetised benefits over the length of the system need to inform the investment recommendation. The two primary factors that will drive an ESO recommendation are:

c. **Monetised benefits**, when monetised benefits are higher than the forecast solution cost.

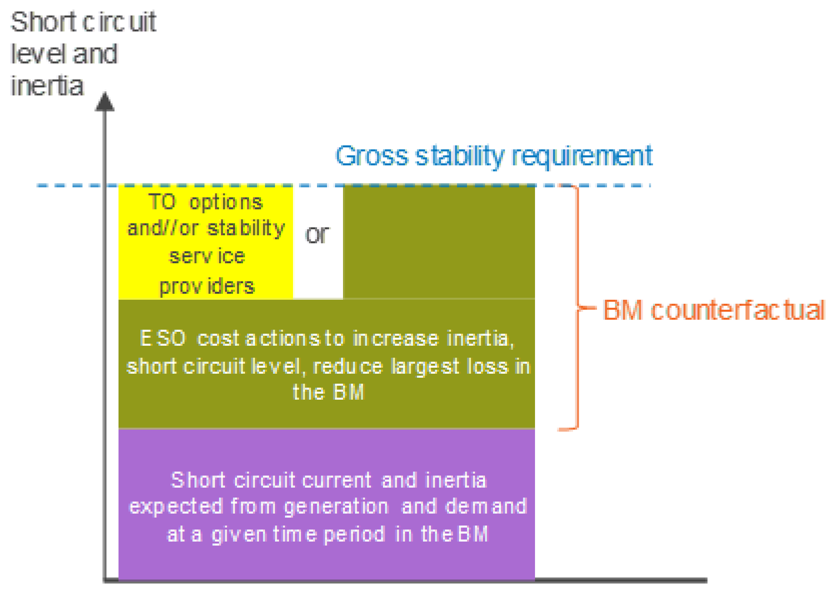
This implies investing in the proposed solution will provide a more economical and efficient way to manage stability in the long term when compared to the ESO paying for the equivalent services in real-time via the Balancing Mechanism (BM).

Justification based on monetised benefits

The ESO currently relies on the inherent capabilities of synchronous generators participating in the BM to provide inertia, short circuit current and dynamic voltage support. The ESO takes actions in the BM to address any shortfall which would lead to system instability. The ESO hopes to see savings on constraint costs. To estimate this saving, the ESO forecasts the constraint and utilisation costs they will pay for accessing and using the short circuit level and inertia via the BM.

Constraint cost refers to the bid and offer price the ESO pays (for the MW) to get a generator onto the system to provide stability support, together with another generator reducing its generation or turned off elsewhere on the system to maintain the balance of supply and demand.

The aim here is to find the solutions which deliver additional benefits to the consumers, in the form of net savings. This is achieved by replacing services which will need to be procured via the BM with lower cost proposed options. In some future instances, the ESO expects a shortfall in the BM to procure for stability. Figure 6.4 shows how proposed options replace services from the BM to meet stability requirement. The ESO uses cost-benefit analysis (CBA) to compare forecast investment costs and monetised benefits over the solution's life to inform this investment recommendation.



In this case, the ESO expects the remaining requirement (i.e. gross requirement minus existing compensation) can be satisfied by generators with mandatory service agreements (MSA) (or other contractual obligations).

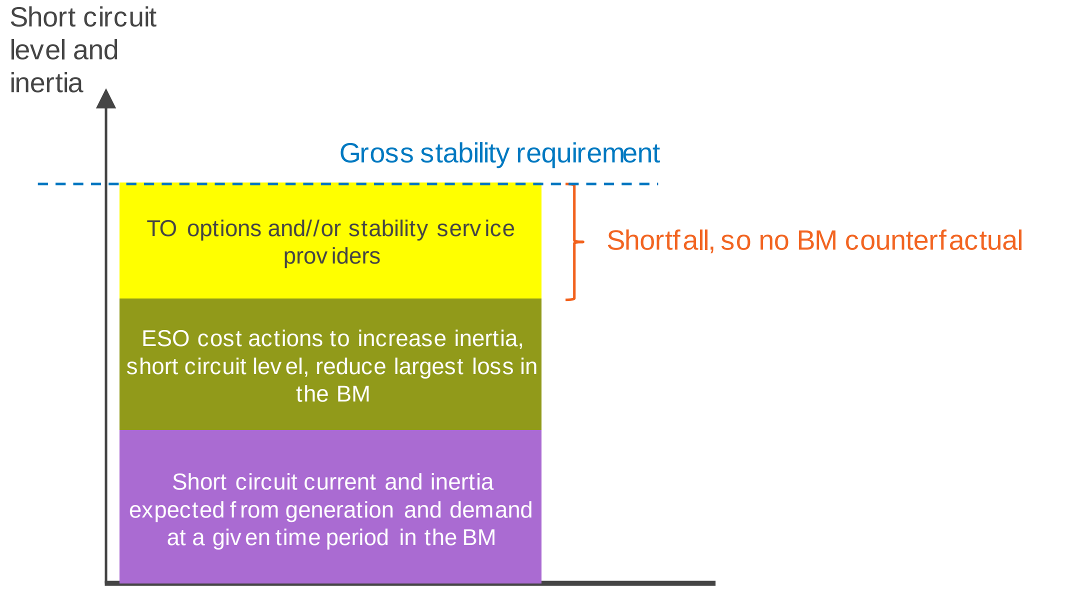
Investment recommendations made in this case focuses on the monetised benefits. It is possible for the ESO to secure Stability Services in real-time via the BM. The aim is to explore potential solutions which provide overall savings to the consumers.

Figure 6. 4: Proposed options replacing services from the BM to meet stability requirement

d. Operational security requirement, when there are insufficient means to provide stability support and securely operate the network. This implies the forecast stability requirement in the future is higher than is forecast to be available via the BM or other means.

<u>Justification based on security and operability</u>

Given the rapid changes in generation and demand backgrounds, there may be times in the future where there will be insufficient BM services available to meet the stability requirements within a region. If such situation is observed in the analysis, the ESO will then focus on verifying the credibility of the assumptions leading to such a situation. If deemed credible, the most cost effective solution to resolve the situation will be pursued. *Figure 6. 5*: shows how proposed options provide the stability requirement as sufficient services cannot be procured from the BM.



In this case, the ESO expects to have insufficient stability support available and cannot satisfy the requirement by using generators with MSAs.

Investment recommendations made in this case focus on the operational security requirement. There is a risk that the system will be inoperable in real-time if nothing is available to provide additional stability.

Figure 6. 5: Proposed options providing the stability support needed to meet requirement as sufficient services cannot be procured from the BM

6.19 Investment recommendations will be based on the above mentioned two primary factors. As a general principle, if there are several options which meet the requirements and satisfy either of the two primary factors, the CBA chooses the most economical and efficient options. This is described in more detail in the section “Cost-benefit analysis”.

The High Voltage management process

Regional approach – determining the most economical and efficient solution for High Voltage management Process

6.20 Voltage is a localised property of the system which means that requirements vary from one region to another. The voltage control requirements are determined by the configuration of the local network and the nature of generation and demand in that region. Since reactive power, unlike real power, cannot be sent across long distances due to the reactance of the transmission network, voltage control is most effective when applied close to the problem. Voltage issues can therefore be grouped into regions and assessment of each region conducted separately. The high voltage management process looks into the reactive power required for high voltage control on a regional basis.

Screening process – selecting and prioritising regions

6.21 The ESO uses a screening process to help identify and prioritise the region(s) which should be further explored through detailed power system and cost-benefit analysis. This should bring consumers the best value by ensuring that the secure, economical and efficient development of the network focuses on challenging regions first. The screening process considers four main factors which are in line with the NOA assessment principles – cost, network change, likelihood and lead time.

- Cost: The focus is on the historic spend in each region to procure Commercial services for managing high voltages. A high historic spend in a region suggests heavy reliance on the BM and ORPS, which suggests potential benefits of conducting an assessment to evaluate the best options to provide future reactive support in the region.
- Network change: This refers to any significant changes of the system in the future, including new generation (including embedded generation), major generator closures, commissioning of new cables etc. Regions which do not associate with a high historic spend, but which are set to see some significant changes that contribute to an increasing need for reactive support should be assessed.
- Likelihood: This is an assessment about how likely the above two factors will materialise. For example, if the high historic spend was due to a routine maintenance outage, it will be considered more likely than spend due to a long outage caused by a fault.
- Lead time: This refers to the length of time between the system need and the typical lead time to deliver an option in the region of interest. For example, if a compliance concern will arise soon after any options can be sourced to meet the requirements, there is an urgency to assess the region.

6.22 The ESO will request feedback from the TOs as to which region(s) they believe should be assessed. This includes any compliance concerns in their networks.

6.23 The ESO will discuss any compliance concerns raised by the TOs and agree a plan to assess these concerns. The discussion will consider when the compliance issue may materialise and the lead time of potential options to resolve the issue.

6.24 The four factors mentioned above in 6.18, together with the TOs' feedback, will be used to help determine the region(s), as well as the backgrounds and conditions that the ESO will consider in the assessment. For example, conditions which are associated with high historic spend and are expected to persist or grow in severity will be analysed. The ESO will apply these conditions to future backgrounds which show similar characteristics to the system when those high historic spends arose.

Creating network models for analysis

6.25 In this high voltage Management Process, the ESO will use the GB system planning models produced in accordance with the SO-TO Code (STC) . Future backgrounds based on Future Energy Scenarios (FES) and system conditions considered appropriate in accordance with the NETS SQSS will be applied to the models for assessment.

6.26 TOs and DNOs will provide relevant data to support the ESO in preparing the models for analysis.

Identifying requirement

Collaborating with TOs/DNOs to explore options from existing assets

6.27 The ESO collaborates with Network Owners, TOs and DNOs, to ensure a consistent methodology is applied when it comes to planning and developing the transmission system. TOs are obliged by their transmission license to plan and develop their transmission network in accordance with the NETS SQSS. DNOs have a key role in enabling a whole system approach to address some of the future requirements in the transmission system while maintaining compliance of their distribution system.

6.28 The ESO shares the initial view of areas of priority with the relevant TOs and DNOs. The ESO aims to ensure consistent methodology, models, backgrounds and sensitivities are considered across all analyses. TOs and DNOs provide feedback about their networks in the relevant areas. The feedback will help the ESO to optimise existing assets prior to quantifying the system needs in those areas in details. To ensure the transmission system is planned and developed in an economical and efficient manner, the ESO should only proceed with new requirements once existing network assets are optimised.

6.29 Where available, the ESO engages with the system operator function of the distribution companies.

Analysing the size of the reactive power requirement

6.30 The ESO identifies the reactive power required to control voltage based on system analysis results. The requirement varies depending on the future backgrounds and system conditions. It is not practical to fully analyse all combinations of backgrounds and conditions. Hence, the ESO selects snapshots using historic records assisted by data mining techniques and engineering judgement to represent a reasonable number of variations of backgrounds and conditions. The same four factors, which were considered during the screening stage (i.e. cost, network change, likelihood and lead time), are used to help with the selection.

6.31 The ESO collaborates with the TOs and DNOs to identify the reactive power required for the transmission networks.

6.32 The diagram below illustrates how the analysis to identify the reactive power required may be structured. The example shows variation in demand assumptions. The selection of the specific study backgrounds and system conditions, which set out the analysis, however depends on the characteristics of the region of interest.

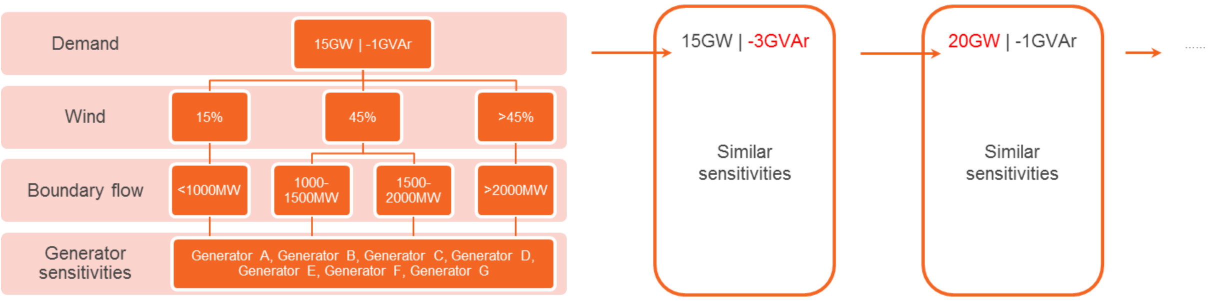


Figure 6. 6 Example of backgrounds and conditions considered for analysis

6.33 The reactive power required depends on what the ESO expects the system will need in the future to maintain voltages within the NETS SQSS limits. To determine the reactive power required for any region of the network the following steps are applied:

1. Set up analysis with selected credible backgrounds and system conditions
2. Analyse to check if the NETS SQSS requirement can be met with existing reactive power compensation and generators which are predicted to run
3. If the NETS SQSS requirement can be met, note the generators running in the region of interest and move on to the next sensitivity analysis

4. If the NETS SQSS requirement cannot be met
    a. If applicable, consider using different combinations of generators in the region of interest which are accessible via the BM
        i. Simulate constraint (bid and offer) actions until the voltage control requirement is satisfied
        ii. Note the generators running in the region of interest
    b. Consider suitable transmission solutions
        i. Simulate investment in new transmission assets at different locations until the voltage control requirement is satisfied
        ii. Note the size of new reactive power compensation plant(s) required and the location they are connected at. This is used to define the reactive power required and the most optimum location for solutions to meet the need in the region
    c. Continue to the next analysis

6.34 The recorded generators running under each analysis will be used to formulate the voltage rules. This is described in more detail in the section *"Creating voltage rules"*.

Calculating effectiveness factors

6.35 To allow a fair comparison to be made for all potential options, effectiveness factors are used when the ESO assesses options. The effectiveness of an option is directly linked to its point of connection and determines the amount of reactive power required to meet the requirement. This will change the total volume expected to be invested or procured. For example, if a unit A was assessed to be 50% effective and unit B 100% effective, to resolve the same issue the system would need to use twice as much reactive power from unit A than B. Unit A would need to be significantly cheaper to have the same benefits.

6.36 Effectiveness changes with certain system conditions, for example with certain outages. The ESO calculates effectiveness factors for each point of connection against consistent (set of) background to ensure all providers are treated equally.

6.37 The examples below are all aimed to be illustrative and provides approximations of potential differences in effectiveness. This will change when specific technical assessment for each region is completed. Provider A in green, Provider B in red.

Example 1

Provider A and B are connected at the same site. The site is run solid. The two different providers have similar reactive ranges.

The providers would likely have the same effectiveness factor.

Note: If the site is run split, the providers would likely have different effectiveness factors.

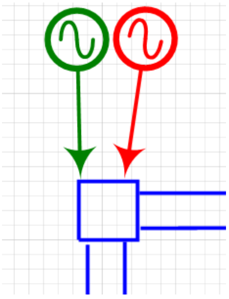


Figure 6. 7

Example 2

Provider A and B are connected at different, adjacent, sites, but sites that are geographically close together.

The providers would likely have similar effectiveness factors.

Note: Distance in the diagram is indicative only.

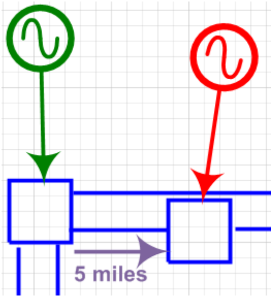


Figure 6. 8

Example 3

Provider A and B are connected at different, adjacent, sites, but sites that are geographically far apart.

The providers would likely have different effectiveness factors.

Note: Distance in the diagram is indicative only.

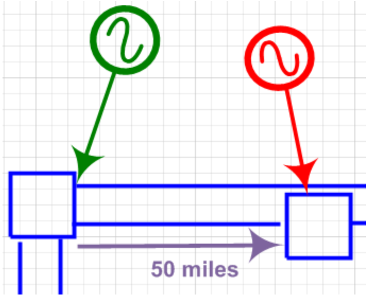


Figure 6. 9

Example 4

Provider A and B are connected at different voltage levels. Provider B is connected at 132kV in the DNO network.

The ESO expects the options close to the source of the issue will have higher effectiveness factors.

If, for example, the source of the issue is at the transmission network, then Provider B that is connected at a 132kV voltage level is likely to be less effective than Provider A. Providers connected at lower voltages than 132kV, in this example, would be expected to be even less effective.

Alternatively, if, for example, the source of the issue is at the distribution network[28], then Provider B is likely to be as effective (or more effective in some cases) than Provider A.

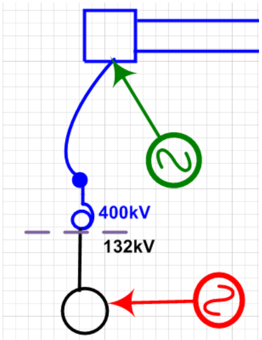


Figure 6. 10

Example 5

The reactive power required is set specifically for a defined region. The region has been defined based on potential effectiveness.

Provider A is inside the defined region and Provider B is outside the defined region.

Providers outside the region are assessed as only being ineffective at resolving the issue.

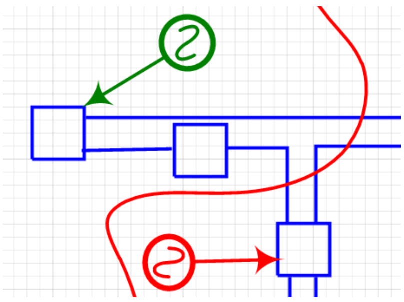


Figure 6. 11

[28] The Power Potential Project, which aims to create a new reactive power market for distributed energy resources (DERs), will provide further insights into effectiveness of options connected to the distribution network. The ESO will learn from the Project and continuously improve their understanding of effectiveness.

6.38 Many factors affect the effectiveness of an option, such as its size, where and how it will connect to the network. Effectiveness factors are relative to a reference point in the network. The ESO chooses reference point(s) in the network based on where it is most effective to implement reactive power compensation to meet the requirement of the region of interest. Through system analysis the ESO calculates the effectiveness of various available transmission-level connection points with respect to the reference point(s).

6.39 For distribution-level connection points, the ESO works with the relevant DNOs to calculate the effectiveness factor of an option. The DNO will calculate the impact of a distribution-connected option to the closest GSP(s). With this information, the ESO can then calculate the effectiveness factor of a distribution-connected option with respect to the reference point in the transmission network. Where available, the ESO engages with the system operator function of the distribution companies.

6.40 In an example below, system analysis suggests it is most effective to implement reactive power compensation at substation Y and that 100MVAr of reactive power absorption is required to meet the system requirement.

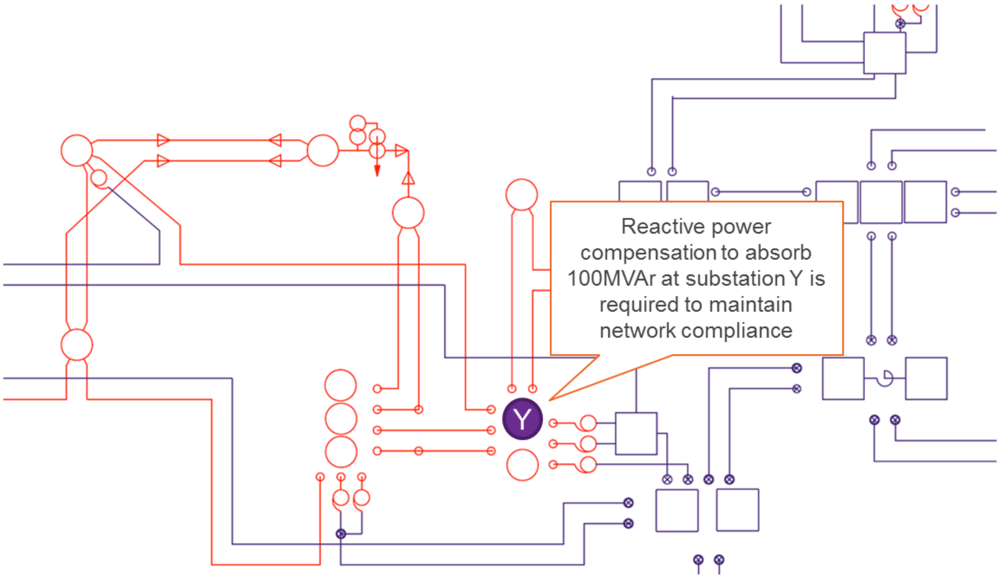


Figure 6.10

6.41 Next, the ESO calculates the effectiveness for options connecting at substation Z with substation Y as the reference point. The ESO models reactive power compensation to absorb 100MVAr at substation Z and test it with selected backgrounds and conditions. In this example, analysis results show that (on average) implementing a reactive power compensation to absorb 100MVAr at substation Z reduces the compensation required at substation Y from 100MVAr to 25MVAr.

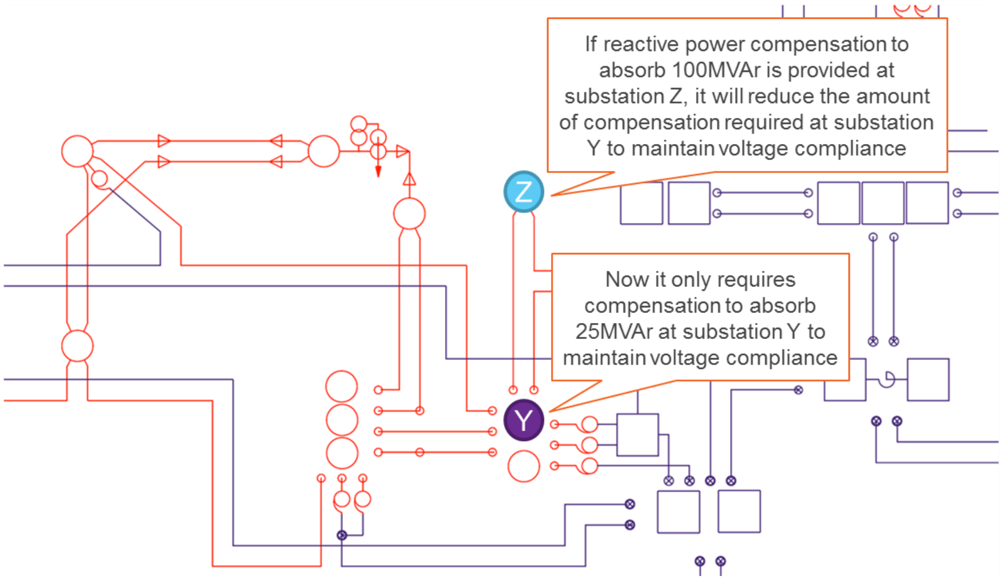


Figure 6.11

6.42 The ESO can then approximate the effectiveness for any options connecting at substation Z as (100-25)/100 = 0.75 with respect to the reference point.

$$Effectiveness\ factor = \frac{original\ compensation\ at\ ref.point\ Y - resulting\ compensation\ at\ ref.point\ Y}{size\ of\ option\ at\ Z}$$

Communicating requirements

6.43 The reactive power required to control voltage will be communicated to relevant parties in the form of “equivalent reactive power compensation to absorb X MVAr at location Y”.

6.44 The ESO also provides information on the effectiveness of reactive power compensation or services installed away from location Y. This information could be presented in a heatmap. All effectiveness factors are relative to the same reference point(s). This is most likely to be the same reference point(s) stated in the requirement i.e. “location Y” for consistency.

6.45 The ESO will provide the same information on requirement to all potential option providers. Such information will be provided to the TOs using the System Requirement Form – Voltage (SRF-V). This uses a similar format and structure as the SRF used in the current NOA for network boundary flow. The same information will be provided to the DNOs and Commercial service Providers via the Tender Process.

6.46 For the avoidance of doubt, this does not imply other information which the TOs and DNOs currently have access to in accordance with the likes of SO-TO Code (STC) or Connection and Use of System Code (CUSC) for network planning purposes will be provided to all parties due to confidentiality reasons.

Requesting & collecting options

6.47 The ESO will invite potential solution providers including TOs, DNOs and Commercial Service Providers to propose options to meet the reactive power for voltage control requirements.

6.48 Any parties interested to have their options considered by the ESO should respond to the invitation to propose options.

6.49 The TOs should respond using the SRF-V while the DNOs and Commercial service Providers should respond via the Tender Process.

6.50 For the avoidance of doubt, all options received will be assessed against each other using the same criteria. The different submission process reflects the difference in funding mechanisms - TO options will be recovered via the present transmission regulatory framework, while DNO and Commercial service options will be paid via the Balancing Service Contract. The ESO considers and assesses all options in the same CBA. See the section "Cost-benefit analysis" for more details.

6.51 The option collection process for each party is as follows:

Branch 1 – TO options

The exchange of option information between the ESO and the TOs will be by means of the System Requirement Form – Voltage (SRF-V). The outline of the SRF-V structure is shown in Table 6.1.

Table 6. 1 Outline of System Requirement Form - Voltage

SRF-V Part	Section title	Details
A	Requirement	Information on requirement in SRF-V Part A will be the same as the information published as part of the Request for Information (see Branch 3 for more details).
B	TO proposed options	TOs provide the information on their proposed options.
C	Outage requirement	TOs provide the expected outages required to connect new assets associated with their proposed options.
D	Not applicable	N/A
E	Option costs	TOs provide the costs on their proposed options. Information should include, but is not limited to: Capital cost, annual breakdown of cost, operation & maintenance cost, WACC etc.
F	Publication information	TOs specify the information which they give consent to the ESO to publish. The ESO will request consent from the TOs to publish the same level of information consistent with the way information from a DNO option or a Commercial service option will be published when the Tender Process concludes.

6.52 System requirements are sent to the TOs using SRF-V Part A. Unless stated otherwise, this also acts as the prompt to the TOs to propose options.

6.53 TOs are expected to submit their options to the ESO using SRF-V Part B, Part C and Part E. All costs supplied in the submission should be in current financial year base prices. SRF-V Part D is not used in the high voltage and stability management process.

6.54 The SO reviews the costs that the TOs submit with their options and check that they are reasonable. The SO checks the costs that the TOs submit against a range of costs for plant and equipment that the ESO has gained from recent experience. If any costs are outside of the range, the SO discusses the costs with the relevant TO. If, following discussions the ESO still believes that the costs are outside of the expected range and will unduly affect the CBA, the ESO can omit the option from the CBA.

Branch 2 – DNO options

6.55 In the long term when a regulatory funding mechanism for DNO options is agreed, it is expected that DNO options will follow a similar route as TO options, but presently a suitable regulatory funding mechanism is not in place for the DNO options. Until a suitable funding mechanism is established it is expected that the DNO options will be paid via the Balancing Service Contract; hence DNO options will follow the same route as Commercial service options in the short term. Therefore, DNOs who wish to propose options should respond via the Tender Process.

Branch 3 – Commercial Service Tender Process

6.56 The ESO publishes the requirements to inform potential Commercial service Providers as part of a Request for Information (RFI). This includes the technical requirements which a

Commercial service must meet to participate in the Tender Process. The ESO uses the RFI to gather information about options that could relieve the high voltage and stability issues. Where applicable, the ESO may directly proceed with a tender process without an RFI. In general, the ESO would like to understand the following before a decision to tender is made:

- The ability of the market to provide Commercial service options as alternatives to Network Owner options to control high voltage
- The level of interest to provide a Commercial service to meet the identified long-term needs
- The likelihood of achieving a more economical and efficient overall solution by considering a wider range of options
- The delivery timescale of market-based options
- Preferred contract options

6.57 The RFI information pack will include an indicative timeline for the Tender Process, including when a decision to tender will be made.

6.58 The ESO decides whether to tender based on the information received from the RFI. The decision will be published alongside a final timeline for the Tender Process.

6.59 If a decision is made to tender, the ESO will publish the Tender Process information pack with selected contract options. The ESO expects the requirements published in the Tender Process information pack to be the same as those published in the RFI information pack, and the assessment methodology to be consistent with this methodology document. Any exception will be stated in the Tender Process information pack. Details in the Tender Process information pack supersede the details from the RFI.

6.60 Any parties interested to have their Commercial service options considered by the ESO should respond to the Tender Process. Any responses should use the proforma published as part of the Tender Process information pack.

Creating voltage rules

6.61 Voltage rules are created to indicate the minimum number of generators required to meet voltage control requirements in a region. The voltage rules are formulated using system analysis results. This approach loosely simulates the close-to-real-time process for voltage management. Studies against generator sensitivities, as illustrated in the previous section, are carried out for each selected set of conditions to help determine the minimum number of generators required and define the voltage rules. Since generators differ in sizes, each generator will be assigned a size coefficient to reflect their different reactive power capabilities.

6.62 The ESO uses these voltage rules with the constraint cost modelling tool to simulate year-round system operation. The number of bid and offer actions required to maintain system voltages within the NETS SQSS can then be estimated.

6.63 The constraint cost saving for each proposed option can then be estimated. Representing those variations of study backgrounds and system conditions in the CBA is crucial to the credibility of the estimated constraint cost saving. These backgrounds and conditions will be built into the voltage rules and hence considered in the CBA.

Assessing options

6.64 When the ESO receives options from potential providers (TOs, DNOs, Commercial service Providers), these options need to be modelled and analysed so their actual impact to system voltages can be understood. The assessment often includes many options; and it may be necessary to group a few options together to create the solution which can meet the system requirement in a region. It may also be more economical and efficient to group options from various providers together i.e. combining TO, DNO and Commercial service options, to meet the requirement. It is however inefficient and impractical to always assess – model and analyse - all possible groups of options. Therefore, the assessment process set out below is used to keep the modelling and analysis at a practical level.

6.65 The ESO will assess the options selected in the CBA and ensure those options satisfy the service and technical requirements before the final recommendation is made and the Tender Process concludes.

6.66 The ESO intends to analyse as many options and combinations as practically possible. Only if the number of options available means there are too many possible combinations, the ESO will perform a pre-assessment selection. For the avoidance of doubt, this pre-assessment selection is designed to keep the assessment practical for the high voltage management Process; the overarching principle of finding the most economical and efficient solution still applies.

Pre-assessment (applicable when a high number of options are available)

6.67 The ESO bases the pre-assessment selection on two main factors - effectiveness and cost. The pre-assessment aims at reducing the number of options to keep the number of possible combinations practical.

6.68 The ESO first calculates the equivalent effective MVAr compensation each option provides with respect to the same (set of) reference point(s) (effective MVAr). The relevant effectiveness factor is applied to each option according to its point of connection and its effective MVAr is calculated.

6.69 The ESO then considers the cost of the option. As the process considers options from TOs, DNOs and Commercial service Providers, it is expected that the costs of options will cover a range of service terms. Hence the cost per year of each option is used for comparison. See the section “Cost-benefit analysis” for more details on calculating the cost per year for each option.

6.70 The ESO considers the effective MVAr and cost per year of each option. A cost-effectiveness factor will be calculated for each option in the format £/effective MVAr per year.

6.71 Options are then ranked according to their cost-effectiveness factors. The options with greatest cost-effectiveness will be selected for the CBA.

Cost-benefit analysis

6.72 The cost-benefit analysis, as mentioned in previous sections, provides investment recommendation based on two primary factors – monetised benefits or security and operability. As a general principle, if there are several options which meet the requirement and satisfy either of the two primary factors, the CBA chooses the most economical and efficient options.

How does the ESO estimate constraint cost?

To estimate constraint cost, the ESO uses the same constraint cost modelling tool as NOA – AFRY’s BID3. This provides consistency with NOA. The ESO uses BID3 to model a European economic dispatch and a GB constrained dispatch (re-dispatch). More information on BID3 can be found in section 2 of the NOA Methodology.

The tool is used to work out constraint (bid and offer) actions required to maintain voltage compliance against future simulated scenarios. The criteria applied to evaluate constraint actions for high voltage control is different to those used by NOA to determine network boundary flow related constraint actions. The criteria is linked to the minimum number of local generators required on the system to maintain voltage compliance by means of voltage rules. This requirement is informed by analysis on credible future backgrounds and system conditions.

BID3 applies voltage rules to simulate the bid and offer actions required to maintain voltage compliance. The focus here is to represent the reactive power capability of generators while keeping the MW cost as low as possible, therefore the cost to move a plant to its minimum stable generation position is priced. Where applicable, footroom requirements will be considered.

The high-level process for estimating constraint cost using BID3 is outlined below.

1. Run an economic market dispatch
   The BID3 model is dispatched for each future energy scenario.
2. Run a network constrained re-dispatch

Apply the forecast boundary capabilities and constraints based on the latest FES database and NOA investment recommendations. Re-dispatch the network as per the previous step.

3. Extract hourly data for pertinent plants for the voltage rules
   For the areas under consideration and according to the voltage rules determined from the technical studies, extract the hourly data relevant for all options under consideration.
4. Examine the hourly data to see what is required to fulfil the rules
   For each option, examine in turn the hourly data to see whether the rules are complied with or what actions need to be taken for them to be complied with. This then creates a list of actions for each option which need to be taken for every hour for the validity of the rules and for each scenario.
5. Cost the actions required based on bid and offer prices and minimum stable generation
   The cost of the bid and offer actions is taken from the assumptions made within the BID3 model and the actions required to meet the voltage rules costed.

How does the ESO estimate utilisation cost?

Utilisation cost will be dependent on a range of factors, such as the following:

- Rate: The ESO applies the current ORPS rate[29] or the contracted rate where applicable.
- Point of connection: Utilisation varies depending on where an option is and the network topology at its point of connection.
- Service duration: Duration an option will be active i.e. how often the ESO expects an option will be required to control high voltages.
- Equipment used: The different equipment used to provide the Commercial services affects how often and how long an option will be used.
- System needs: For example, whether the reactive power capability is required pre-fault and/or post-fault will impact how often and how long an option will be used.

It is impractical to calculate utilisation based on fixed point system analysis as utilisation varies with system conditions. To fairly recognise the utilisation cost, the ESO estimates it based on how the BM units or newly proposed options are anticipated to be used.

6.73 The CBA considers various factors, including but not limited to:

- System requirements for controlling high voltages
- Point of connection of option
- Effectiveness
- Assessment period
- MVAr capability provided by proposed option
- Flexibility to offer only part of the MVAr capability of proposed option
- Earliest-in-service date (EISD)
- Costs including costs to cover outages requirements

6.74 In previous sections, system requirements, point of connection and effectiveness have already been discussed in detail.

6.75 Assessment period is defined as the years over which the future voltage control requirements are reasonably clear and certain. This should be the same as the period for which the Tender Process requests for options.

6.76 Options may provide different MVAr capability in each year.

[29] The rate which the ESO pays BM providers for utilisation in £/MVArh under the default payment mechanism. The utilisation payment is updated monthly in line with market indicators as set out in Schedule 3 of the Connection and Use of System Code (CUSC).

6.77 In some cases, a provider who can offer only part of the MVAr capability of its proposed option may help achieve an overall solution of lower cost to consumers. The ESO considers this flexibility when they select options to form the most economical and efficient solution(s).

6.78 EISD refers to the earliest date when an option will be available to provide the required reactive power.

6.79 The cost to provide the service can be split into capital costs and operational costs. All costs submitted should be in current financial year base prices. Table 6.2 below provides the various element of costs to be included as the capital cost and operational cost in TO options, DNO options and Commercial service options.

Table 6. 2 Details of capital and operational costs for each type of providers

Option providers	Capital cost	Operational cost
TOs	• Cost of the new assets associated with an option • WACC to be applied to regulated assets	• Maintenance • System access • Other ongoing operational cost associated to the option
DNOs	• In the short term while the DNO options will be paid via the Balancing Service Contract, the cost of DNO options should be submitted via the Tender Process and in the same format as required by the Tender Process.	

Commercial service Providers	Cost of connecting any new assets associated with an option to the electricity system (transmission or distribution)	• As per contract, which may include:
		  ○ Availability payment
		  ○ Utilisation payment

6.80 The capital cost is any infrastructure cost that will be incurred by a Network Owner (TOs or DNOs). The ESO applies the weighted average cost of capital (WACC) to any network infrastructure costs that will be incurred due to an option. The ESO will seek this information directly from the relevant Network Owner(s). The capital cost should be submitted as a spend profile, which indicates the financial year in which the capital will be spent Costs should be in a single, specified price base year which is consistent with the base year used for tender bids.

Table 6. 3 Example of spend profile

Year	2020/21	2021/22	2022/23
Cost £m	5	10	8

6.81 The operational cost should include any maintenance, system access and other ongoing costs. The operational cost will be applied for each year that the option is utilised. The operational cost submitted may vary by year.

6.82 The benefits that each option provides will be discounted at the social time preference rate as laid out in the Treasury Green Book[30]. This process results in the present value (PV) of each cost and benefit.

6.83 The ESO first calculates the equivalent effective MVAr compensation each option provides with respect to the same (set of) reference point(s) (effective MVAr). The relevant effectiveness factor to each option is applied according to its point of connection and its effective MVAr is calculated.

6.84 The ESO then calculates the cost of providing an effective MVAr for each option. The operational cost per effective MVAr will be calculated as the PV operational cost per year divided by the quantity of effective MVArs provided.

[30] https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-governent

$$PV\ Op.Cost\ per\ eff.MVAr = \frac{PV\ Operational\ cost\ per\ year}{eff.MVArs}$$

6.85 The capital cost will be calculated as the PV capital cost divided by the product of the quantity of effective MVArs and the number of service years. Service years is defined as time that the option will be available and cost-effective within the assessment period.

$$PV\ Capital\ Cost\ per\ eff.MVAr = \frac{PV\ Capital\ Cost}{eff.MVArs\ \times\ Service\ Years}$$

6.86 The sum of the operational and capital costs per effective MVAr will be the cost per effective MVAr for the option.

$$PV\ Cost\ per\ eff.MVAr = PV\ Op.Cost\ per\ eff.MVAr + PV\ Capital\ Cost\ per\ eff.MVAr$$

6.87 The goal of the CBA is to find the most economic and efficient solution(s) to the problem for the GB consumer. An optimisation will be carried out across all years within the assessment period simultaneously to find the cheapest solution(s). This is to take into account the capital cost of each option which is independent of the number of years that the option is considered optimum.

6.88 With the cost per effective MVAr calculated, the bids will be stacked, with the lowest cost per effective MVAr at the top, and the highest at the bottom. In general, bids will be selected from the top first until the system requirement for effective MVArs has been met. The stack order may be altered if more cost-effective combinations become apparent.

6.89 The ESO may conduct this process for every year individually or across the entire assessment period as deemed appropriate.

6.90 A provider may submit an optimal bid in one year, but this does not guarantee the bid will be optimal in subsequent years if lower cost options are available. The lowest cost solution(s) over the entire assessment period will be chosen. Note that in some cases this may result in a more flexible or smaller option that is more expensive per MVAr to be chosen.

6.91 Within each yearly stack, the ESO forecasts the cost of procuring the system voltage need through the BM. This will be done by modelling future GB electricity markets using the latest future energy scenarios and assessing within each settlement period which generators will be able to provide a solution to voltage issues. The BM costs for procuring the need will be again converted into a cost per effective MVAr which will be placed within each yearly stack to compete against the submitted options.

6.92 An example of the stacks and the selection of winning bids (highlighted green) is shown below in Table 6.4. Please note that the costs shown are not reflective of any forecast, they have simply been chosen for demonstration purposes.

Table 6. 4 Example of selection of options based on cost per effective MVAr to achieve a solution with most economical and efficient total cost

System need: 200MVAr				
Provider name	**Flexible?**	**Provider effective capability (MVAr)**	**Cost per effective MVAr (cost/MVAr)**	**Cost**
Provider 1	Yes	50	10	500
Provider 2	Yes	100	14	1400
Provider 3	No	25	15	375
Provider 5	Yes	50 (25 procured)	18	450
Provider 4	No	50	17	
BM	Yes	200	22	
Provider 6	Yes	100	30	

6.93 The total cost in Table 6.4 is 500+1400+375+450=2725. Note that Provider 5 is selected ahead of Provider 4 even though Provider 5 has a higher cost per MVAr. This is because Provider 5 is more flexible and allows the system need to be met exactly. Using Provider 4 would result in the system need being exceeded by 25MVAr and result in a higher total cost (500 + 1400 + 375 + 850 = 3125). There is a cheaper (although not the cheapest) solution where Provider 4 is selected ahead of Providers 3 and Provider 5. This solution has a cost of 500 + 1400 + 850 = 2750 and exactly 200MVAr is procured. In some cases, the system operator may allow excess MVAr to be procured if this would result in a lower cost for the consumer and pose no operational issues.

6.94 The CBA recommends the options which should be taken forward. Given the size of the investments and the short lead times, these recommendations are a single lifetime decision. This means that when an option is recommended, that recommendation persists until the asset or service contract expires. This is different to the normal annual NOA least-worst regret (LWR) recommendations which are reviewed annually. Where a recommendation is marginal, the decision may be to reassess at a later date when there is greater certainty of the need. This is only possible where the EISD of the option is ahead of the need and so the option can be delayed.

The Stability Management Process

Regional approach

6.95 At a regional level, the distribution of regional inertia, short circuit level, dynamic voltage support can influence the stability of the local network and its users. The regional stability requirements are determined by the configuration of the local network and the nature of generation and demand in that region. Since short circuit current and reactive power, unlike real power, cannot be sent across long distances due to the reactance of the transmission network, it is most effective when applied close to the problem. Stability issues can therefore be grouped into regions and assessment of each region conducted separately. The stability management process looks into the stability needs on a regional basis.

Screening process – selecting and prioritising regions

6.96 The ESO uses a screening process to help identify and prioritise the region(s) which should be further explored through detailed power system and cost-benefit analysis. This should bring consumers the best value by ensuring the secure, economical and efficient development focuses on challenging regions first. The screening process considers future trends of generation and demand and their potential impact of system operability due to decline in regional system strength (short circuit levels), regional inertia and regional dynamic voltage support.

6.97 The ESO will request feedback from the TOs as to which region(s) they believe should be assessed.

Creating network models for analysis

6.98 The ESO will start with the GB system planning models to produce and update elements within it to ensure the models are fit for this purpose. Future backgrounds based on Future Energy Scenarios (FES) and system conditions considered appropriate based on expected trends of decline in regional system strength (short circuit levels), regional inertia, regional dynamic voltage support will be applied to the models for assessment.

Identifying requirement

Collaborating with TOs/DNOs to optimise existing assets

6.99 This part of the process is similar to the one from high voltage management project (please see paragraph 6.27-6.29).

Analysing the size of the stability requirement

6.100 The ESO identifies the stability requirement based on system analysis. The requirement varies depending on the future backgrounds and system conditions. It is not practical to fully analyse all combinations of backgrounds and conditions. Hence, the ESO selects snapshots based on data mining techniques and engineering judgement to represent a fair number of variations of backgrounds and conditions. For stability analysis, the ESO considers future outlook of FES scenarios on regional short circuit level, regional inertia and regional dynamic voltage. This allows ESO to choose a generation and demand background to be studied in detail. The ESO determines the regional stability requirements by running time series fault simulations in an RMS tool (Power Factory) for a selected generation and demand background. The ESO carries out sensitivity scenarios to complete its detailed analysis. The ESO also considers how often such a need could arise over the future years.

6.101 The regional stability needs are determined by understanding regional voltage and frequency behaviours within a period of a transmission system disturbance (transmission system faults can last for up to 140ms), at fault clearance and immediately after a fault clearance and for at least 500ms after fault clearance. The stability of voltage and frequency waveforms allows ESO to understand the risks on the transmission system and to quantify the stability requirements.

Calculating effectiveness factors

6.102 To allow a fair comparison to be made for all potential options, effectiveness factors are used when the ESO assesses options. The general principle used to calculate the effectiveness of an option is similar to the one in high voltage project (please see paragraph 6.35-6.42), instead of calculating effectiveness of options to provide reactive support, the effectiveness of option to provide short circuit current and/or dynamic reactive support is calculated for stability management process. More details will be published in any stability tender based on regional stability needs.

Communicating requirements

6.103 Communicating process for system requirement between ESO and stakeholders is similar to the one from high voltage process (please see paragraph 6.43-6.46), instead of using SRF-V, SRF-S is used to exchange data.

Requesting & collecting options

6.104 This part of the process is similar to the one from high voltage (please see paragraph 6.47-6.60), instead of using SRF-V, SRF-S is used to exchange data.

Assessing options

6.105 Process is again very similar to high voltage management (please see paragraph 6.64-6.71), a cost effective factor is calculated for each option in the format £/effective MVA per year (as opposed to the £/effective MAVr per year used in high voltage management project) in order to compare and rank them in the CBA process later on.

Cost-benefit analysis

6.106 In principle, a similar methodology to high voltage is used (please see paragraph 6.72). The stability cost benefit analysis will be dependent on drivers behind each region's stability requirements. For example, in Scotland the ESO's stability needs are primarily driven by low short circuit level, whereas in other areas of GB there may be different drivers. The stability cost benefit analysis will also take account of active power export for each option and discount providers due to the cost of balancing their active power elsewhere. The ESO will publish detailed assessment methodology applicable to a stability tender as part of a tender process.

High Voltage and Stability Process conclusion

6.107 Based on the results of the CBA, the ESO recommends the solution which should be taken forward. The recommended solution could consist of only TO option(s), only DNO option(s), only Commercial Service Provider option(s), or any combination of these three types of options. If the CBA concludes that none of the options proposed in the process provides benefits against forecast BM cost to control high voltages, the ESO may accept no Network Owner options and/or Commercial Service Provider options.

6.108 If the recommended solution consists of TO option(s), the ESO will write to the relevant TO(s) to inform them of the recommendation to support an investment case.

6.109 If the recommended solution consists of Commercial Service Provider option(s), the ESO will contact the relevant provider(s) after publishing the tender outcome and proceed with procuring the selected option(s) using the Balancing Service Contract.

6.110 If DNO option(s) are recommended, in the short term while the DNO options will be paid via the Balancing Service Contract, the ESO will proceed with the DNO option(s) in the same way as with any Commercial Service Provider options.

Tender outcome

6.111 Tender outcomes will be announced as soon as reasonably practicable once the analysis and other relevant verification and approval process conclude. Tender outcomes will be published on the ESO website.

Regional report

6.112 A regional report on the high voltage and stability management process will be published after all the analysis and tender activities conclude. The report includes driver, requirement, effectiveness and recommended solutions. It is expected that most of the information will have been made available at the various stages in the process already by the time the report is published.

6.113 The report will not include sensitive information unless agreement has been established with the information owner or is permitted by legislations or code.

6.114 On publication the report will be placed on the ESO website as a PDF document.