Danish Energy Agency

ERAV
Electricity Regulatory Authority of Vietnam

Grid Codes: Recommendations for Connection of Offshore Wind Power

October 2020

EVNNLDC

ENERGINET
ASSOCIATED ACTIVITIES

Table of content

Document history

Rev.	Date	Author	Reviewer	Description
0	2020.05.25	Knud Johansen	ERAV, DEA	Document released - draft
0.1	2020.06.08	Knud Johansen	ERAV, DEA	Revised after comments from ERAV and DEA
0.2	2020.10.04	Knud Johansen	ERAV, DEA	Language correction in all sections. Section 1 - Circular C55 added to the list of acronyms. Section 2 – text revised and reference to the DEA road map report is introduced. Wind map removed. Section 4.2 – Circular C55 added to the list of relevant docs. Section 5 – updated and the recommendations summarized at the end of the section.
1.0	2020.10.08	Knud Johansen	ERAV	Document released for final comments

1. Acronyms

The below table lists acronyms used in this document.

AS	Ancillary Services
C21	Circular 21 - On regulating the pricing method for electric power system's ancillary services and the procedure for scrutinizing a contract for provision of electric power system's ancillary services.
C25	Circular 25 – The regulations on electricity transmission system
C39	Circular 39 – The regulations on electricity distribution system
C40	Circular 40 – The procedure for dispatching of national power system
C55	Circular 55 – Technical requirements and management and operation of the SCADA system
CGM	ENTSO-E Common Grid Model
DSO	Distribution System Operator
GC	Grid Code
GL	European Guideline
NC	European Network Code
NC ER	Network Code for emergency and system restoration
NC HVDC	Network Code on HVDC systems
NC RfG	Network Code on connection of all types of generators
NSCOGI	The North Seas Countries' Offshore Grid Initiative
P2X	Power-to-X (P2X) comprises several ways to convert electricity into energy storage
PGM	Power Generating Module
PoC	Point of Connection – the point where a facility is electrically connected to the grid
PCC	Point of Common Coupling – the delivery point where power from a facility is transferred
QD106	Decision 106 - The procedure of identifying and operating ancillary services
RSO	Relevant System Operator – could be a TSO, DSO or CDSO, depending on the specific grid
RTO	Regional Transmission System Operator
SO GL	ENTSO-E System Operation Guideline
TSO	Transmission System Operator
TYNDP	ENTSO-E Ten Years Network Development Plan
VN	Vietnam

2. Introduction

Current plans to establish offshore wind power facilities in Vietnam are quite ambitious, according to various sources. Investors are ready and just waiting for permission to build. The wind power part of the generation portfolio is expected to be increasing a lot in the near future. The demand for electricity is increasing to support the growth of the Vietnamese social welfare and industrial sector.

The potential for offshore wind in Vietnam is enormous and based on regional screening exercises a technical potential of offshore wind capacity deployment in the order of 160 GWs has been identified. Further screening and project details can be found in the DEA report recently published - "Input to roadmap for Offshore Wind development in Vietnam" [8].

To enable the integration of such a huge amount of offshore wind, the relevant legislation, and connection and operational codes must be in place ahead of initiating the projects.

This document aims to introduce some of the technical challenges and recommendations on grid connection requirements to maintaining a stable grid system with a huge amount of wind power from the offshore sites.

3. Scope of document

Provide recommendations on offshore wind connection requirement code based on Danish/European experience.

Provide overview of Danish/European experience with offshore wind connection in network codes.

Based on the need to connect offshore facilities in Vietnam, work closely with ERAV to develop a structure as well as the requirements for offshore wind power connection.

This document is provided as deliverable 3.4 under the VN DEPP DE2 ToR agreement.

4. Grid codes in Vietnam

The current VN grid code relevant for offshore installations consists of the following documents.

4.1 Grid connection code

C25 Circular 25 – "The regulations on electricity transmission system"
The document states a mix of requirements among others some of the requirements to be met in order to be granted a grid connection, some other requirements to the transmission grid system operator as well as requirements for grid system operation and providers of ancillary services. The document also includes a description of some of the responsibilities of the various parties involved.

C30 Circular 30 – "Amendments to some articles of C25"
The document states corrective amendments to C25 and C39.

4.2 System operation code

C40 Circular 40 – "The procedure for dispatching of national power system"

The document states operational procedures for dispatching power-generating facilities.

C55 Circular 55 – “Technical requirements and management and operation of the SCADA system”
The document states requirements for the SCADA systems applied by the various parties.

C31 Circular 31 – “Amending and supplementing a number of articles of C28, C40 and C44”
The document states corrective amendments to C40.

More detailed discussions of and investigations into the need for connections must be conducted to evaluate additional requirements for the current grid connection and operational codes. The following section includes our first-hand recommendations on the current grid codes.

5. Grid codes for VN offshore facilities – recommendations

The grid code documents listed in chapter 4 are intended for onshore facilities, but connection and operational requirements must generally be the same, no matter where a generation facility is located. The primary and fundamental objective of any grid code is to support grid stability and security of supply no matter where the generation and demand facility is located physical.

The **recommended** strategy for grid connection codes for offshore facilities in Vietnam is to use the current requirements or a reorganised/updated set of requirements, maintaining the same fundamental requirements for all types of generation facilities and for any facility location.

The latest publication on offshore wind in Vietnam is the DEA publication “Input to roadmap for Offshore Wind development in Vietnam”, September 2020 gives some advices on where the optimal locations is seen from a wind resource perspective. How the power can be evacuated to and transmitted by the Vietnamese grid system in safe and efficient manner needs further grid stability and load flow studies. It’s very essential to analyse where the facilities might be connected to the grid and the related stability impact of the new facility connected. The location of the possible point of connection might have impact on the usability of the required capability.

The EU network code for connection of generation facilities is the NC RfG [1] which covers all types of generation technology and any placement of the facilities – onshore as well as offshore. Some required functionality might be reviewed for increased flexibility as regards long transmission line paths and long submarine cables. Depending on the distance to the onshore delivery point, where power from a facility is transferred, a DC-based transmission line / submarine cable might be relevant to reduce grid losses, and so, a request for an HVDC system connection code could pop up soon, depending on the planning of the grid system design for connecting offshore facilities. Such a request could be met as part of a connection code revision cycle, and not explicitly be introduced for offshore installations, as it could increase the efficiency of transmission over long distances onshore as well. Since 1999, Denmark has had the same set of connection requirements for both onshore and offshore wind power facilities. The physical location of a wind power facility is not essential for the required capability, but the operational usability of the capability might be affected by the location.

About the current grid connection codes, it is vital to give a more precise definition of the point of connection (PoC) for facilities, but this is not only relevant for offshore installations. An updated and modernised specification of the PoC must be included in the revision of the current VN connection codes. One example that clearly calls for a revision is mixed systems, which includes batteries, PV panels, micro hydro's, wind power generators etc. One of the main challenges is to determine where the capability of a PGM is to be verified. Options include at the PoC, at the facility terminals and at the PCC. This must be specified in the grid connection code. It's **recommended** to review the current grid connection code and clarify the mentioned topics on the connection point.

Detailed grid analyses and system interaction studies must be done to define the various operational parameter ranges that will be apply to a specific facility. The parameter ranges must be selected within the parameter ranges specified in the minimum design requirements stated in the grid connection code.

Based on grid integration studies and dynamic stability assessments, the current operational code and procedures might need to be adjusted, but generally, operation and scheduling should be the same for all parties and any fuel type in a generation or demand portfolio. All parties must be treated equal. It's **recommended** to remove all discriminatory aspects in the current operational codes.

Naturally, the services they offer will be different as their capabilities at the PoC are different. One example is the need for voltage stabilisation services in a facility's PoC. If the PoC is located far from the wind power facility, for example 60 – 80 km away, the value of reactive compensation from the facility might be quite low or non-existent when it comes to voltage stabilisation at the PoC because of cable losses and transmission cable capacity. Such issues must be considered regarding system operation when performing the detailed grid planning studies and the designing the daily operational regime. Such considerations apply not only to offshore connections but also to long onshore transmission lines. Detailed coordination with grid system planning and adherence to connection and operational code specifications must always be in place; otherwise, the grid could be in risk of having a dynamic instability or to be inefficiency.

With purpose of reducing the losses in transmitting active power over long distances a grid connection code for HVDC systems might be needed. Further detailed studies of the VN grid system focusing efficient transmission of active power over long distances included grid systems to offshore installations. Such studies could result in utilizing the DC technology instead of AC technology which implies that the DC systems must be specified in the connection [2] and operational code [3], [4]. It's **recommended** to add a grid connection for grid connection of HVDC systems and review the operational code for operating the connected HVDC systems.

Our recommendations are based on the outcome of grid analysis and expert discussions on integration of offshore based renewables in Europe during the last 15 years. The next two sections are intended to reflect the challenges and the outcome from the European expert discussions until now.

The **recommendations** can be summarized as the following:

1. The VN grid connection code must be the same for off- and onshore facilities and transparent to all parties.
2. The allocation of an offshore facility PoC must be supported by detailed grid stability assessments.
3. The technical justification for allocation of a PoC must be clearly specified and transparent to all parties.
4. All parties must be treated equal and face the same set of minimum design requirements for grid connection. independent of physical location, technology, and ownership.
5. Application of HVDC links to offshore wind power facilities might be beneficial if location is far from the coast.
6. All parties must be treated equal and face the same set of operational requirements independent of physical location, technology, and ownership.

6. Offshore wind power challenges in Europe

In Europe, a huge amount of wind power (approx. 450 GW) is projected for the coming 10 – 20 years. In relation to the discussions on grid stability impact, ENTSO-E regularly holds expert consultations and workshops addressing, among other things, the aspects are described in the following.

Offshore wind is abundant and has the potential to generate high capacity in many areas while enjoying decreasing cost levels. Thus, it is an attractive contributor to the European Green Deal. However, the pressure is on to deliver within a short time frame. The alternative, that is not delivering the prerequisite offshore wind generation and creating the necessary infrastructure, will mean not fulfilling the decarbonisation targets of the European Green Deal.

Considering the following topics:

i) depending on technology and distance the expected average connection cost of offshore wind to the onshore transmission system is significant and will increase in time as,

ii) the distance to shore is expected to further increase, since available nearshore areas have already been developed,

iii) lead time for offshore generation is shorter than for infrastructure and,

iv) space for cable routing to shore is limited, and it is obvious that unprecedented grid and spatial planning, engineering, construction and financing efforts are required offshore to facilitate the large-scale roll-out of offshore wind. The same applies onshore, as electricity must be transported farther to reach the consumer in a way that is consistent with offshore grid developments. Existing onshore grids were developed step by step over almost a century. Now, the offshore transmission infrastructure and related onshore connections and reinforcements must be built in only a few decades. This requires very holistic concept planning and infrastructure construction.

The large-scale roll-out of offshore wind comes with certain challenges. ENTSO-E identifies six key challenges:

1. **Costs:** massive investments must be made in offshore wind power generation, and offshore and onshore transmission infrastructure. Both distance to shore from offshore generators and onshore corridors for grid connection systems will increase over time. Financial security is needed for these necessary investments, and stranded investments must be avoided.
2. **Spatial planning:** up to 450 GW of offshore wind capacity will have to be allocated and the space available for cable routing and landing points as well as onshore grid systems are expected to become scarcer. Coordinated marine and onshore spatial planning is needed.
3. **Integrated perspective over time - across land, sea and sectors:** the main load centres, industry and large cities are often far away from offshore generation. Solutions for integrated development and operation of the offshore and onshore transmission grids and solutions for market design must ensure overall affordability, sustainability, security, timeliness and reliability of power supplies.
4. **System balancing:** a massive share of variable RES with a locally high degree of simultaneous generation patterns causes high ramps at onshore connection points, calling continuously for more advanced flexibility products in balancing markets to satisfy operational flexibility, e.g. ancillary services. This operational flexibility can be provided by other sectors as well. Thus, while a high share of offshore wind may unlock the potential to decarbonise other sectors, these sectors could be able to deliver important services to the electricity sector. A global system view is needed to organise this properly. An efficient market design must ensure the optimum match of physical reality and markets.
5. **System security:** very high shares of variable renewables can, depending on the system, have adverse effects on e.g. frequency stability, voltage stability, admissible line loading and voltage profiles. This is already seen in

small isolated systems today but can be expected in more extensive areas in the next decades as well, if the evolution of the system is not carefully planned. Systems and technical requirements need to be prepared in due time.

6. **Environmental protection and public acceptance:** the relevance of actions that will facilitate public acceptance is increasing as the opposition towards offshore and onshore wind generation and transmission systems grows in many countries and thus endangers the decarbonisation targets.

Perspectives for addressing the above challenges are currently being discussed to ensure efficient development and integration of offshore and onshore energy systems and realising the European Green Deal.

From the essential stakeholder's organisation, the ENTSO-E have taken an initiative to propose options for further detailed implementation discussions among politician and technical experts as described in the next section.

7. ENTSO-E's view on offshore developments

To grasp the opportunities and tackle the challenges listed in the previous chapter, ENTSO-E identifies six basic pillars of successful offshore development [7], supporting offshore wind integration in electricity systems over time, across land, sea and sectors, promoting system security, cost efficiency and the ambitions of the European Green Deal.

7.1 Facilitation of grid connections

Offshore wind generation must be connected to the onshore transmission grids and electricity must be transported farther to load centres and consumers.

Development of offshore and onshore grid systems must be coordinated in a holistic approach of integrating new offshore connections, interconnections and grid reinforcements. Careful planning is needed at an early stage to keep the overall costs of offshore development as low as possible and create technically sound, environmentally friendly and efficient future electricity supply systems, in the interest of the society. A holistic perspective is essential.

The TSOs/RTOs/DSOs are responsible for overseeing that combined grid systems across land and sea are developed, built and operated in secure, cost efficient and sustainable ways. This responsibility covers the application of long-term grid system views, comprising the complete generation, demand and storage portfolio and considering technology developments while planning and coordinating across borders.

ENTSO-E covers both the onshore and offshore transmission infrastructure in the TYNDP, and offshore grid infrastructure planning will continue to be an integral part of future TYNDPs. Unprecedented grid and spatial planning, engineering, construction and financing efforts will be required in the years to come. TSOs are prepared to step up their role in these areas, e.g. by engaging more in offshore spatial planning and contributing with technical and economic analyses of selected scenarios.

Wind generation potential, associated transmission needs, and spatial constraints should be assessed jointly by policy makers, authorities, regulators, portfolio managers, project developers and TSOs to achieve a joint view on the offshore wind potential and how to integrate this Where relevant, this should include regional joint assessments across borders. This joint view will serve as a foundation for developing holistic, spatial offshore development plans, including offshore wind potential and transmission infrastructure aimed at minimizing costs and environmental impact.

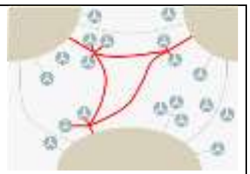
7.2 Combination of technologies and designs

As stated in earlier ENTSO-E investigations on offshore grid infrastructure, ENTSO-E expects the complexity of the offshore system to require a combination of various technical solutions to ensure overall system efficiency [6].

The grid developments of the Northern Seas may serve as an example. In the North Sea, the use of various grid technologies (AC and DC) and of various designs developed in parallel is expected:

1. point-to-point interconnections between member states,
2. radial connections between offshore wind power facilities and the onshore systems,
3. radial connections of several wind power facilities to hubs that are radially connected to the onshore system
4. hybrid projects, (combination of offshore wind connections and interconnections) and
5. multiterminal offshore hubs connecting multiple platforms and member states (with or without offshore wind being connected)

Designs 3) and 4) may also comprise solutions that include other forms of energy, i.e. energy hubs with sector coupling solutions.

				
1) Point-to-point IC	2) Radial offshore facility to shore	3) Radial hub-to-shore	4) Hybrid project	5) Multi-terminal offshore hubs

Reference: ENTSO-E NSCOGI study 2012 [5]

The above grid designs can also be seen as development stages: real examples of stages 1) to 4) already exist, while examples of stage 5) multi-terminal offshore hubs are under consideration at early design stages.

The first smart sector integration visionary projects are even under consideration, that include links to P2X facilities and thereby link different energy sectors. This can evolve onshore and offshore solutions at an overall level. A multi-sectorial planning approach should be applied to facilitate optimal exploitation of offshore energy, basically allowing it to flow into the sector where it provides the most value. Studies and initiatives are summarised in ENTSO-E's TYNDP 2018.

7.3 Realisation of synergies with modular planning

ENTSO-E expects a modular and stepwise offshore development, with choices being made for each project based on technical, environmental and economic parameters for the project at hand. However, beside this organic growth, decisions must always include a long-term system view as well and are therefore, to some extent, influenced by assumptions on the developments of the overall system.

ENTSO-E provides a regularly updated planning support tool, the TYNDP, which gives a long-term overview of infrastructure developments and projects. ENTSO-E ensures that these tools also support infrastructure planning in relation to offshore grid developments.

Compact hybrid offshore projects can be envisaged in cases where scheduling and technology required for interconnection and wind connection match. The cooperation of all stakeholders in all the countries involved is essential in these cases.

Early analyses of offshore development from both ENTSO-E (2011) and North Seas Countries' Offshore Grid Initiative (NSCOGI – 2012), identified theoretical synergies and savings from coordination for offshore wind capacity levels beyond 60-80 GW for the Northern Seas. EU member states and national regulators are exploring such synergies and savings further through specific project studies within the North Seas Countries' Energy Cooperation.

Synergies from coordinated infrastructure developments in general are confirmed in each update of the TYNDP. This joint TSOs' planning instrument promotes consistent planning methods across borders as well, which is important when planning large offshore infrastructure projects.

7.4 Implementation of more intelligent integrated system operations

The offshore development and simultaneous change in the onshore electricity generation portfolio already challenges system stability in some areas today as flows and operational patterns change. These phenomena are expected to become more widespread. System operation (onshore and offshore) must be integrated and optimised as one system, applying similar methodologies and approaches.

The "one system" approach is a prerequisite for secure and long-term cost-efficient system operation. The approach helps to identify the needs and realise the potential for flexibility and storage, as well as to manage variability of RES generation and of loads. Such an integrated perspective promotes the development of more intelligent integrated system operations.

More intelligent and integrated system operation is needed to achieve the European Green Deal while guaranteeing the required security margins in the system.

To unlock these benefits, fundamental system engineering studies are necessary, which must be led by TSOs as they are responsible for system stability. These studies will require data from offshore wind project developers and suppliers of electrical infrastructure to promote interoperability of subsystems. Typically, these data are not shared between developers and asset suppliers due to intellectual property rights concerns. TSOs, however, can serve as neutral entities to facilitate such studies.

A generally important prerequisite for offshore grid development is interoperability of offshore HVDC systems from different vendors, meaning that technology vendors must deliver compatible, modular systems. This is important to avoid lock-in effects. TSOs will further trigger this development by promoting standardisation, which will incentivise vendors to strive for interoperability. This is not expected to appear automatically.

7.5 Development of proper regulation

Regulatory measures are required at both overall and project levels. In general, ENTSO-E expects the existing energy market regulation framework to work offshore as well as onshore. The overall system must be treated as one integrated system. For this to happen, the following issues should be addressed:

- Unbundling: consistent unbundling rules for both onshore and offshore systems ensure neutrality, non-discrimination, fair competition and security of supply. ENTSO-E strongly recommends the application of the same rules onshore and offshore.

- **Equal opportunities:** all offshore development investors should meet the same conditions and should be treated equally, ideally across country borders, to ensure efficient offshore development. Regulatory frameworks of different member states must be made compatible with each other and, for example, incentivise forward-looking investments to deliver the most economic, efficient and reliable offshore transmission infrastructure from a sustainable perspective. Forward-looking investments might need anticipatory investments, which should therefore be facilitated by regulatory frameworks.
- **Roles and responsibilities** of involved investors need to be clear. Offshore generation connections should adhere to the same principles as onshore connections (non-discriminatory, cost efficient, long term robust, system compatible). Currently, responsibility varies between countries, but some studies, TSOs' own investigations and recent developments indicate that an allocation to the TSOs is the best way forward. Stranded investments, inefficient infrastructure developments or discrimination must be avoided
- **Cost efficiency and market integration**: to realise the required investments, price signals, market integration (bidding zones) and support mechanisms must efficiently promote security of supply, cost efficiency and the targets of the European Green Deal. New offshore wind power facilities will be integrated into the existing EU electricity markets. The concept of offshore bidding zones facilitates their efficient integration into the electricity market, even if connected as a hybrid project. Neither major changes, nor exemptions of current regulatory and legal frameworks seem to be necessary. Bidding zones might need to be adjusted when structural congestions appear due to changing generation portfolios,
- **Reduction of Financial Risks** financing investments in offshore infrastructure will be challenging. High risk is a key driver of costs. Thus, adequate regulatory frameworks should help attract capital by providing a good balance between incentives and risks. The market set-up should be known before investments are made in order to provide a robust framework and financial security for investors, who need to know the if's and how's of investment returns.
- **Role of TSOs:** to realize efficient development, secure system operations and long-term sustainability in the combined power system across land and sea, ENTSO-E believes that TSOs should have a similar role offshore as onshore. Such a role will promote a "one system" approach, and it would include responsibilities for overall system engineering studies, integrated system operations, setting requirements for offshore projects and developing and owning required grids offshore as well as onshore.

7.6 Cost reduction and innovation

Grid connections and grid reinforcements are major components of the overall costs of offshore wind power, and this share is expected to grow as wind power facilities are realised further off from coasts and consumption centres. This means that optimising grid connection costs is an essential condition to keeping tariffs at acceptable levels. Several innovative cost reduction measures have already been identified and implemented by the TSOs, and further innovation is needed.

7.6.1 Standardisation

Standardisation across a given portfolio of projects is an essential factor in cost reduction as exemplified by transmission capacities (e.g. 700 MW, 2000 MW), wind farm connection types, and AC voltages (e.g. 33-to-220 kV, 66 kV direct connection) and DC voltages (320 kV, 525 kV).

7.6.2 Innovative grid solutions

Radial offshore hubs (wind park clusters with 900 MW DC or 700 MW AC radial connections to the onshore grid) and hybrid solutions (e.g. Krieger's Flak combined grid solution) have led to both cost reductions and reduced environmental impact in the past. Future developments, e.g. multi-terminal systems, are expected to provide further cost-reducing and operational benefits.

7.6.3 Multi-use platforms

The development and operation of marine infrastructure affect the environments of the oceans and influence marine ecosystems. Offshore platforms that combine multiple functions (environmental monitoring, connections of test sites, marine culture…) within the same infrastructure can offer significant benefits in terms of economics, optimising spatial planning and reducing the environmental impact.

ENTSO-E will continue to strengthen the focus on cost-optimised solutions and push development within generation and grid system technology by creating the framework for grid connections at affordable prices both onshore and offshore.

8. References

The following documents are used as references in this report.

#	Description
1.	COMMISSION REGULATION (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators (NC RfG)
2.	COMMISSION REGULATION (EU) 2016/1447 of 26 August 2016 establishing a network code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules (NC HVDC)
3.	COMMISSION REGULATION (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation (SO GL)
4.	COMMISSION REGULATION (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration (NC ER)
5.	ENTSO-E NSCOGI study 2012 https://www.entsoe.eu/about/system-development/#the-north-seas-countries-offshore-grid-initiative-nscogi
6.	Navigant "Connecting Offshore Wind Farms" – July 2019, Connecting Offshore Wind Farms, A Comparison of Offshore Electricity Grid Development Models in Northwest Europe https://guidehouse.com/news/energy/2019/navigant-compares-offshore-grid-connection-models
7.	ENTSO-E Position paper on Offshore Development: https://www.entsoe.eu/2020/05/29/entso-e-position-on-offshore-development/
8.	DEA publication "Input to roadmap for Offshore Wind development in Vietnam", September 2020 https://danish-energy-agency.mynewsdesk.com/pressreleases/roadmap-to-offshore-wind-power-development-and-policy-recommendations-for-vietnam-3036544

9. Further reading on offshore wind power

#	Description and link
1.	Florence school of regulators - Network Codes - self-study programs: https://fsr.eui.eu/tag/network-codes/
2.	WindEurope: "Offshore wind in Europe" – key trends and statistics 2019, Feb 2020
3.	WindEurope "Our energy, our future", November 2019
4.	North Seas Energy Forum https://www.benelux.int/nl/kernthemas/holder/energie/nscogi-2012-report/

Energinet
Tonne Kjærsvej 65
DK-7000 Fredericia

+45 70 10 22 44
info@energinet.dk
VAT no. 25 94 33 25

Author: KDJ/MDA
Date: 4 October 2020