Integrating Renewable Energy Projects into Grids

Technical Requirements Guideline

RCREEE

Regional Center for Renewable Energy and Energy Efficiency

المركز الإقليمي للطاقة المتجددة وكفاءة الطاقة

جهاز تنظيم مرفق الكهرباء وحماية المستهلك

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Introduction

Energy has become the conspicuous challenge facing the globe. The idea lies on how to manage and meet the energy demand affordably, securely, and within a sustainable framework. Security of supply is a challenge by itself as statistics prove that more than 60% of the world's known reserves of natural gas are in just four countries, and more than 80% of global oil reserves are located in nine countries. Moreover, the depleting fossil fuel resources have made the supply security issue controversial. In terms of affordability, the low carbon resources are still costly to produce at scale. Therefore, it is believed that the energy demand challenge can only be met through a mix of different resources and technologies. Through integrated resource planning, countries consider all resources that could cover a broad spectrum of energy needs. Arab countries are falling under the same umbrella of urgent need to follow such route. Arab countries have great potential for RES development, especially the PV and wind technologies. Nevertheless, these resources are still underused.

Almost all Arab countries are showing great interest in exploiting the abundant renewable energy resources, where many of them have already developed quantitative strategic goals for different RES technologies shares in their electricity mix. Such RES strategic goals are directed mainly towards the satisfaction of domestic demand, while seizing the anticipated opportunities for exporting the excess electricity through regional and international initiatives aiming at large-scale renewable power projects in the Arab region.

On the regional level, several collaborative activities are shaped and fostered by individual and joint efforts of the Energy Department in the Economic Sector of the League of Arab States (LAS), and the Regional Center for Renewable Energy and Energy Efficiency (RCREEE). These efforts have led to the approval of the "Pan Arab Strategy for the Development of Renewable Energy Applications: 2010 - 2030" by the Arab Summit. The Arab RES strategy includes targets for the advancement of the renewable sector. Realization of this strategy still needs efforts not only on the policy and regulatory levels, but on the technical level as well. The next step is to support each of the Arab countries in setting their action plans for implementing the strategy as appropriate on the corresponding national scale. Therefore, it is essential to identify the basic milestones in such process. These milestones are – but not limited to - policy instruments, regulatory and institutional frameworks, technologies acquisition and development, integration with grid, investments and financing schemes, regional interconnections, and finally capacity building.

Planning for tangible growth in renewable electricity generation in the Arab region is often accompanied with concerns regarding their integration with existing transmission and distribution grids and the additionally related investments to maintain grid security, reliability and operability. Alleviating these concerns requires proper understanding of the probable effects of renewable energy production variability on many aspects, such as the installed capacity, reserve requirements, frequency control, reactive power/voltage control, system stability, demand variation, network operation and control, and many others.

As a follow up for the implementation of the Arab RES Strategy, the "Renewable Energy Working Group" affiliated to the Arab Ministerial Council for Electricity, at its meeting on the 9th and 10th of October, 2013 in Bahrain, recommended the identification of the minimum technical requirements to integrate different RES technologies into the grids with a focus on PV and wind technologies.

Chapter 1: Regulatory Frameworks for Connecting RES to Grids

Due to the fact the most of the Arab countries have already developed quantitative strategic goals for deploying Renewable Energy Sources (RES) in their electricity mix, it is therefore crucial that they develop coordinated and coherent regulatory frameworks as well. These frameworks shall include standardized procedures for grid connection and access of RES to avoid drawbacks and problems which originate from the lack of a uniform approach for grid connection and access with technical and organizational provisions being uncoordinated. This situation gets more complicated by the massive deployment of new intermittent Distributed Generation (DG – RE) and the contribution of demand response in network and market operations. Consequently, the role of the Transmission System Operators (TSOs) and Distribution System Operators (DSOs) has extended from just taking care of the grids' infrastructure into being user-oriented service providers.

TSOs as well as DSOs are now employing new concepts, and interacting with different actors and a variety of independent grid users. For that reason, it is important to identify the cornerstones that are perceived crucial in planning to integrate RES technologies to the grids and formulating the technical requirements.

This chapter will guide through the regulatory frameworks necessary for grid connection and access. These include the Contractual Framework, Technical Codes (Grid Code, Wind and PV Codes), Impact Studies, and Other supporting regulations.

1.1. Technical Framework

1.1.1. Technical Codes (Grid code – Wind code and PV codes)

The technical codes specify the appropriate minimum standards and requirements applicable to all grid users, specifically the PPs who own a RES power plant - as per the context of this document. The Grid Code acts as the base upon which other special provisions are defined for the large intermittent generation (e.g. wind, PV, etc.). These minimum standards and requirements must be defined for each type of RES power plant and must take into account the voltage level at which the plant is connected. This section will point out the basic characteristics of these technical codes; specific details on these characteristics will come along in Chapter 2

Generally, the technical code(s) shall (but not limited to):

- Specify the criteria and methodology for the definition of the RES power plants. These shall be based on a predefined set of parameters which measure the degree of their impact on the system performance.
- Inherit regular re-assessment (including public consultation) of the system requirements (e.g. integration of RES, smart grids, DG, etc.)
- Define clearly the boundaries of ownership and operation for the RES power plant, the connection facilities and the transmission facilities

- Define minimum conditions for (re)connection to the grid in disturbed/critical operating state, and to set out the criteria by which the RES power plants will be able to execute their control activities in normal and in disturbed operating states.
- Define the coordination requirements and procedures for reconnection after tripping in a transparent manner. Different roles and responsibilities shall also be clearly defined
- Define the requirements on the RES power plant that contributes to secure system operation. These requirements shall aim at avoiding a large disturbance in the grids; including:
    - Frequency and voltage parameters;
    - Requirements for reactive power;
    - Load-frequency control related issues;
    - Short-circuit current;
    - Requirements for protection devices and settings;
    - Fault-ride-through capability; and
    - Provision of ancillary services.

Finally, it is worth mentioning that the process of developing the technical codes, undertaken by the TSO/DSO and reviewed by the National Regulatory Authority (NRA), shall require coordination between all parties. The applicability of the standards and requirements to pre-existing PP shall be decided by the NRA, based on a proposal from the TSO/DSO. The TSO's/DSO's proposal shall be made on the basis of a sound and transparent rationale. Under certain circumstances, a pre-existing RES power plant can be granted derogations.

1.1.2. Impact Studies

If Arab countries are to meet their RES targets and ensures security of supply, large amounts of renewable capacities will be connected to their electricity grids in the next decade. New electricity networks are needed to resolve the capacity constraints for new RES. They have to be strengthened and extended to accommodate the new generation in a secure and cost effective manner. Also, the way in which new grid infrastructure is planned and developed must be renovated and accelerated.
Some studies shall be carried out periodically to ensure the reliable and safe operation of the grid. These are to verify:

- The stead state behavior of the grid;
- The maximum power transfer capability of critical transmission circuits, which will ensure secure and reliable operation of the grid; and
- The behavior of the grid after electromechanical or electromagnetic transients produced by disturbances or switching operations.

For a new connection or a proposed expansion the TSO/DSO must decide which studies shall be carried out to evaluate the impact on the Grid. The magnitude and complexity of any grid extension or reinforcement varies according to the nature, location and timing of the RES capacities that are going to be added.

The basic grid planning studies include load flow studies, short-circuit studies, transient stability studies, steady state stability studies, voltage stability studies, electromagnetic transient studies and reliability studies, etc. as found below:

A. *Steady State Performance (Load Flow Studies)*

Transmission facilities are expected to be within their respective normal thermal and emergency ratings. Additionally, system voltages should also be maintained within normal and emergency ranges. The analysis typically requires hundreds or even thousands of power flows that examines variety of conditions, including the outages of major components in the network. These contingency analyses will be performed with and without the proposed RES power plant, so that the relative impact of the project can be easily identified. Situations that do not meet the criteria will require corrective action, which may involve the addition of new transmission equipment or replacement of old ones.
The TSO/DSO shall perform the load flow studies to evaluate the behavior of the grid for the existing and planned RES power plants under forecast maximum and minimum load conditions on transmission lines loading. For new transmission lines the load conditions that produce the maximum flows through the existing and new lines shall be identified and evaluated. Based on the results of these studies, single and double outage contingency cases shall be developed and analyzed, including outages of multiple transmission circuits on common structures and/or right of way, to evaluate the possible impact of the outage of the critical components on the grid.

The design of the connection of the new plants shall be considered satisfactory when the following conditions are achieved:

- No overloading of transmission lines or other equipment occurs during normal conditions;
- Short term overloading of transmission lines and equipment remains within the pre-established emergency limits for all single-outage contingencies;
- Voltage profiles are within the limits given in the relevant codes.

B. *Transient Stability*

The TSO/DSO shall perform Transient stability studies to verify the impact of connecting a new power plant to the network as it may cause transient or dynamic stability problems during some network disturbances. This requires dynamic simulations of the grid and the plant. Transient stability problems may require changing or installing protection with faster fault clearing times. Dynamic stability problems may require the application of power system stabilizers. The critical fault clearing times are calculated, and power system stabilizers are tuned to address such concerns.

Results of the studies' results show satisfactory grid performance if:

(a) The grid remains stable after single-outage contingencies for all forecast load conditions;

(b) The grid remains controllable after multiple-outage contingencies. In the case of Grid separation, no total blackouts should occur in any grid electrical island.

C. *Short circuit Level*

Connecting new plants may increase the short circuit currents in the grid causing overwhelm to the existing power system protection equipment. Short circuit studies are performed to identify equipment that could be permanently damaged when current passing through it exceeds the design limits, such as switchyard devices and substation buses. The studies shall also identify the circuit breakers, which may fail when interrupting possible short circuit currents. Alternative grid configurations (topology) may be studied to reduce the short circuit current to acceptable values. Such changes in grid configurations shall be subjected to load flow and stability analysis to ensure that the changes do not cause steady-state load flow or stability problems.

Study results shall be considered satisfactory when the short circuit currents are not beyond the design limit of any equipment and the proposed grid topology maintains secure and safe operation.

D. *Voltage Support*

The RES power plants have limited voltage control capabilities. Power flow and dynamic simulation studies should be performed to identify such voltage problems, so that the appropriate voltage support equipment can be selected. A power system analysis software tool should include models for many types of WTs and PV, as well as static VAR compensators (SVCs), and static synchronous compensators (STATCOMs).
Periodic studies shall be performed to determine if the grid is vulnerable to voltage collapse under heavily loaded conditions. A voltage collapse can proceed very rapidly if the supply of reactive power to support system voltages is exhausted. The studies shall identify solutions such as installation of dynamic and static reactive power supplies to avoid vulnerability to voltage collapse. In addition, the studies shall identify safe grid operating conditions where vulnerability to voltage collapse can be avoided until solutions are implemented. Studies shall be conducted to determine the possibility that voltage instability problems may occur in the Grid.

E. *Voltage Ride Through*

Many transmission owners and operators are now requiring RES units to continue operating during severe voltage dips in the network. Often, the interconnection study of a wind farm will include a voltage ride through testing to ensure that it can perform within the criteria of the transmission entity.

F. Frequency Response

While most conventional generators can respond rapidly to system frequency changes, wind and PV plants have limited ability to vary their output. Some grid codes are now requiring RES generators to ramp their outputs up or down in response to system disturbances.

1.2. Contractual Framework

The contractual framework can comprise different types contracts according to the scheme under which these contracts apply. Also, contracts can be coupled together so that one is effective as long as the other contract is effective too. In general, it can be speculated that contracts are of either a commercial or a technical context. This document will focus on the technical contracts. These contracts articulate the commitments to the technical codes and the other technical requirements set by the TSO. The following sections will discuss two types of contract in this regard; the "Network Connection Contract" and the "Network Access Contracts" (sometimes referred to as "Network Use Contract").

1.2.1. Network Connection Contract

The Network Connection Contract is made between the Power Producer (PP) and the TSO/DSO. Under this contract the TSO/DSO allows the PP who owns and operates an RES Power Plant to be connected the grid with a certain capacity (in kW/MW) in accordance to the technical requirements stated in the technical codes, and against certain connection fees. The PP has to specify the feed-in points of the generated energy (normally the points of common coupling (PCC) with the grid). The PP may also provide Ancillary Services or Balancing Energy under this contract. Finally, the TSO/DSO ensures that the RES Power Plant shall remain connected to the grid for the term of the contract provided that the PP fulfills all the technical requirements.

1.2.2. Network Access Contract

The Network Access Contract is made between the PP and the TSO/DSO. Under this contract the TSO/DSO allows the PP to have access (use) the grid for the purpose of transmitting the electrical energy generated from the RES Power Plant within the contracted capacity to the PP's own customers, against a definite Network Access Charge. The PP has to specify the feed-in points of the generated energy (PCC) with the grid, as well as the feed-out point(s) at the customer's side (point(s) of connection between the customers and the grid). The power to be transmitted to each of the customers served by the PP's RES power plant must not exceed the contracted capacity agreed upon in the relevant "Connection Contracts" between the customers and the TSO/DSO. Therefore, in such cases signing the "Connection Contracts" between the PP and the TSO/DSO, and the customers and the TSO/DSO, must precede putting the "Network Access Contract" into force.

For both contracts, there are common provisions specifically related to the technical perspective;

i. Compliance with technical requirements

The TSO/DSO must ensure that the RES Power Plant connection to the grid are in compliance to all applicable national laws and regulations. The detailed technical requirements, technical data, and the characteristics and qualities of the electricity generated resulting from this connection should be either amended to the contracts or referred to as in the technical codes.

ii. Interruption of Connection/Access to the Grid

The TSO/DSO may interrupt or reduce receipt of electricity at any PCC for a reasonable period and for reasonable reasons. Such events could be (but not limited to):

- force majeure
- operations-related interruptions such as testing, repairing, replacing or maintaining repairs, maintenance and upgrade work
- if the security of supply can no longer be ensured

In such cases the TSO/DSO must provide the PP with reasonable advance notice of such interruption, and shall use all prudent and reasonable means to limit the duration and adverse effect of them

1.3. Other Networks Regulations

There are some supplementary regulations that furbishes the RES framework adopted by a country. The following are some examples in this regard:

- ***Connection Charges***

These are the costs that the PP will need to pay, for the studies to be conducted, or toward transmission grid modification or installation of physical connection equipment. Connection charges can be either shallow, deep or be of a combined system. To optimize the connection charging system, it should be designed in such a way that costs and benefits of the RES power plant connection can be optimally allocated to the right player. When shallow connection charges are applied, the PP pays for the connection only and grid reinforcement costs are covered by the TSO/DSO. When deep connection costs are applied, the PP pays for grid connection and grid reinforcement. For that purpose, network connection charges could be shallow but include a locational signal to more optimally allocate costs & benefits of new grid connections.

- ***Network Access Tariff (Network Use Tariff)***

The PP pays the TSO/DSO for the transmitted energy from the PCC to the Delivery Points of each Customer. A single Network Access Tariff is applied for both Peak and Off Peak periods, and for each voltage level irrespective of the distance between the PCC and the Delivery Points. In case where the PCC and Delivery points have different voltage levels, the

Network Access Tariff for the lower voltage level shall be applied. In Egypt, The Network Access Tariff for any Voltage level includes the following:

- the cost of the transmission network on the voltage level in addition to the higher voltages
- The cost of the purchase of network losses equal to the average production cost of the thermal power plants

These charges provide an important source of revenues for the TSO/DSO for operating the electricity network.

- ***Network Access Priority***

The RES power plants has the priority for network access over the conventional power plants. Moreover, plants with the latest Commercial Operation Date have priority over the others, while taking into consideration the grid’s safe and secure operating conditions.

- ***Energy Banking***

The PP has the right to accredit the excess transmitted energy (energy credit) to his customers for their further consumption. However, the energy credit shall not be transferred from one contractual year to the following contractual year. At the end of each contractual year, the TSO is committed to purchase the excess energy at a regulated price and to pay back the PP the amount of network access charge paid for this excess energy. This mechanism is adopted by Egypt.

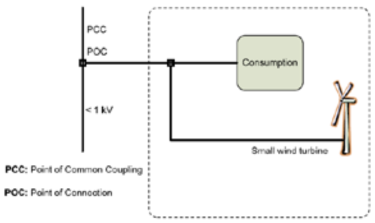
Chapter 2: The Generic RES Code

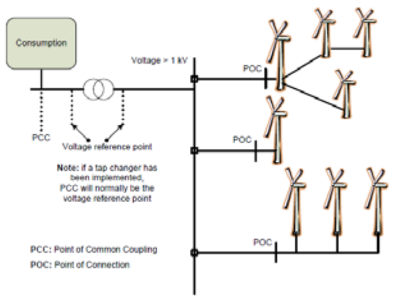
This chapter includes information about the basic content of each of the technical codes/specifications of the transmission and distribution grids to facilitate RES connection to existing and new networks. It includes the minimum technical requirements for connecting Wind Farms/PV Plant projects with different penetration levels to various networks' voltage levels.

Therefore, as a way to harmonize the RES Codes in the Arab region, a Generic Code Format is proposed which contains examples of text, typical graphs, and units. Relevant grid's requirements (numerical values) should be specified according to local grid needs (studies). It has to be mentioned that the included figures in this proposal are provided as examples for clarification only.

1. GENERAL INFORMATION– Wind /PV CODE		RES Technology		Unit
		Wind	PV	
1	The Code naming *It is the official name of this code.*	✓	✓	Text
2	Date of issuing/implementation *The date when this code shall be binding.*	✓	✓	Text

2. GENERAL DATA		RES Technology		Unit
		Wind	PV	
2.1 INTRODUCTION/ OBJECTIVE/SCOPE *This specifies the general specifications and requirements for this code implementation such as:*		✓	✓	Text
3	Geographical Area *Stating the geographical area in which this code shall be binding, such as:* - *the whole country's territories,* - *a region,* - *a certain space and similar.*	✓	✓	Text
4	Capacity Limit *Stating a capacity limit (in k/M/GW) for which the code shall be binding.*	✓	✓	Numerical Range
5	Grid Voltage Level Limit *Stating a voltage limit for which this code shall be binding.*	✓	✓	Numerical Range
6	Grid Grounding Type *Stating the network grounding type at different voltage levels:* *Isolated grounded, directly grounded, others….*	✓	✓	Text
7	Point of Common Coupling (PCC) and Point of Coupling (POC) *Specifying the PCC/POC of the Wind Farm/PV Plant with a grid at which this code shall be binding, unless otherwise stated.*	✓	✓	Text, Figure

<table>
<tr><td></td><td>Example[1]:




Small scale wind power plant   Large scale wind power plant</td><td>✓</td><td></td><td>Figure</td></tr>
<tr><td colspan="2">2.2 DEFINITIONS
General definitions for Terms and Parameter used in this code</td><td>✓</td><td>✓</td><td>Text</td></tr>
<tr><td>8</td><td>Terms and Parameter</td><td>✓</td><td>✓</td><td>Text</td></tr>
</table>

<table>
<tr><td colspan="2" rowspan="2">3. RES-GRID CONNECTION TECHNICAL REQUIREMENTS</td><td colspan="2">RES Technology</td><td rowspan="2">Unit</td></tr>
<tr><td>Wind</td><td>PV</td></tr>
<tr><td colspan="2">3.1 Voltage Ranges</td><td>√</td><td>✓</td><td>✓</td></tr>
<tr><td>9</td><td>Nominal system voltage
The nominal system voltage should be specified in advance, then p.u. values are used.</td><td>✓</td><td>✓</td><td>Numerical [kV]</td></tr>
<tr><td>10</td><td>Absolute maximum operating system voltage
This is the absolute maximum operating voltage</td><td>✓</td><td>✓</td><td>Numerical [kV]</td></tr>
<tr><td>11</td><td>Absolute minimum operating voltage
This is the absolute minimum operation voltage</td><td>✓</td><td>✓</td><td>Numerical [kV]</td></tr>
<tr><td></td><td>Example[2]:
The Wind Farm shall be able to deliver available active power according to wind conditions to the high and extra high voltage grids (>33 and >132 kV respectively) when the voltage at the PCC Point remains within the ranges specified by:
<table>
<tr><th>Voltage range</th><th>Time period for Operation</th></tr>
<tr><td>0.85 pu – 0.90 pu</td><td>Unlimited</td></tr>
<tr><td>0.90 pu – 1.10 pu</td><td>Unlimited</td></tr>
<tr><td>1.10 pu – 1.15 pu</td><td>30 minutes</td></tr>
</table></td><td>✓</td><td></td><td>Table, Figure</td></tr>
</table>

[1] Energinet.dk, “Technical regulation 3.2.5 for wind power plants with a power output greater than 11 kW,” Document no. 55986/10, Technical Regulation 3.2.5, 2010

[2] “Wind Farm Grid Connection Code in addition to the Egyptian Transmission Grid Code (ETGC) Egyptian Wind Code,” March 2014. http://egyptera.org/Downloads/taka%20gdida/Egypt_gridcode_for_wind_farm_connection.pdf

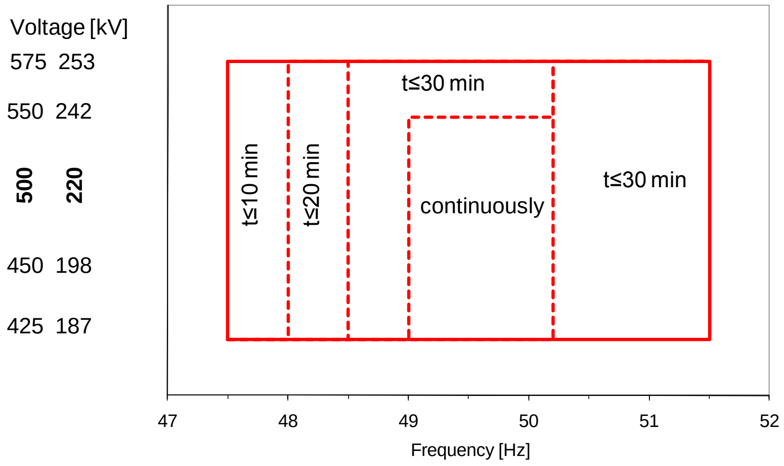
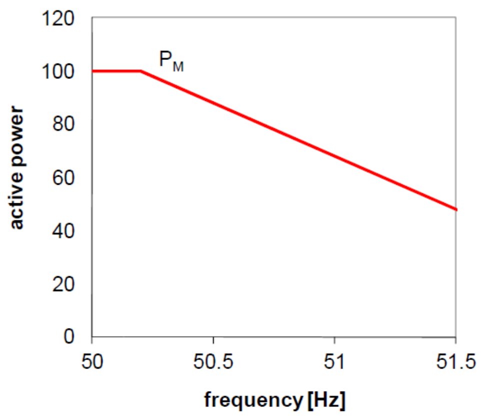
<table>
<tr><td colspan="2">3.2 Frequency Ranges</td><td>✓</td><td>✓</td><td>Text</td></tr>
<tr><td>12</td><td>Maximum system frequency
This is the maximum system frequency at PCC.</td><td>✓</td><td>✓</td><td>Numerical [Hz]</td></tr>
<tr><td>13</td><td>Minimum system frequency
This is the minimum system frequency at PCC.</td><td>✓</td><td>✓</td><td>Numerical [Hz]</td></tr>
<tr><td rowspan="2">14</td><td>Frequency Operating Range:
It is the steady state system operating frequency range at PCC</td><td>✓</td><td>✓</td><td>Numerical Range [Hz]</td></tr>
<tr><td>Example[2]:
The continuous operating range in f 47.5 Hz until 51.5 Hz.</td><td>✓</td><td></td><td>Numerical Range [Hz]</td></tr>
<tr><td>15</td><td>Frequency-time diagram
A frequency versus time figure (if exists).</td><td>✓</td><td>✓</td><td>Table, Figure</td></tr>
<tr><td colspan="2">3.3 Power Quality Ranges</td><td>✓</td><td>✓</td><td>Text</td></tr>
<tr><td colspan="2">3.3.1 Harmonics
These are the harmonics at PCC.</td><td></td><td></td><td></td></tr>
<tr><td>16</td><td>Maximum individual harmonic voltage distortion
It specifies the maximum individual harmonic voltage distortion.</td><td>✓</td><td>✓</td><td>Numerical [%]</td></tr>
<tr><td rowspan="2">17</td><td>Total harmonic voltage distortion
It specifies the total harmonic voltage distortion</td><td>✓</td><td>✓</td><td>Numerical [%]</td></tr>
<tr><td>Example[2]:
The maximum levels of voltage harmonic distortion at PCC for Wind Farm connection:
<table>
<tr><td rowspan="2">Voltage Level [kV]</td><td colspan="2">Level of harmonic voltage distortion</td></tr>
<tr><td>Odd Harmonics %</td><td>Total Harmonics %</td></tr>
<tr><td>> 161</td><td>1.0</td><td>1.5</td></tr>
<tr><td>69.001-161</td><td>1.5</td><td>2.5</td></tr>
<tr><td>< 69 KV</td><td>3.0</td><td>5.0</td></tr>
</table></td><td>✓</td><td></td><td>Table, Figure</td></tr>
<tr><td rowspan="2">18</td><td>Maximum individual harmonic current distortion
It specifies the maximum individual harmonic current distortion.</td><td>✓</td><td>✓</td><td>Numerical [%]</td></tr>
<tr><td>Example[3]: (Small scale PV installation at low voltage 0.38kV)
Each individual harmonic shall be limited to the percentages listed below (IEC 61727:2004).</td><td></td><td>✓</td><td>Numerical [%]</td></tr>
</table>

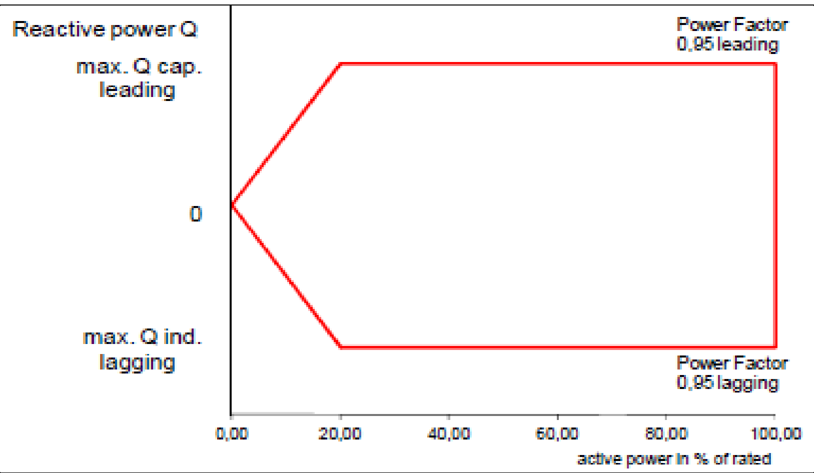
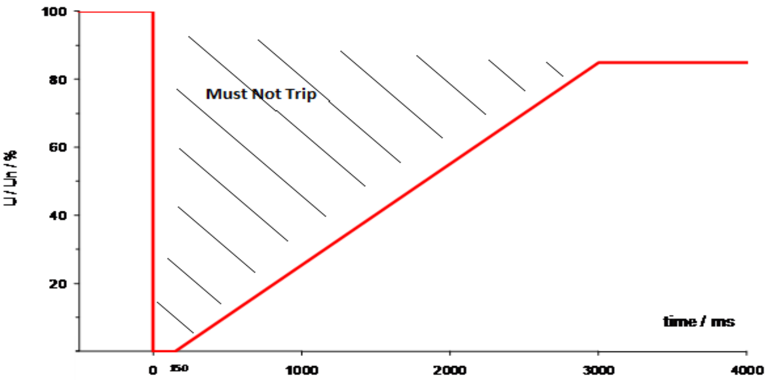
[3] EgyptERA, "Technical Requirements for Connecting Small Scale PV (ssPV) Systems to Low Voltage Distribution Networks," April 2014

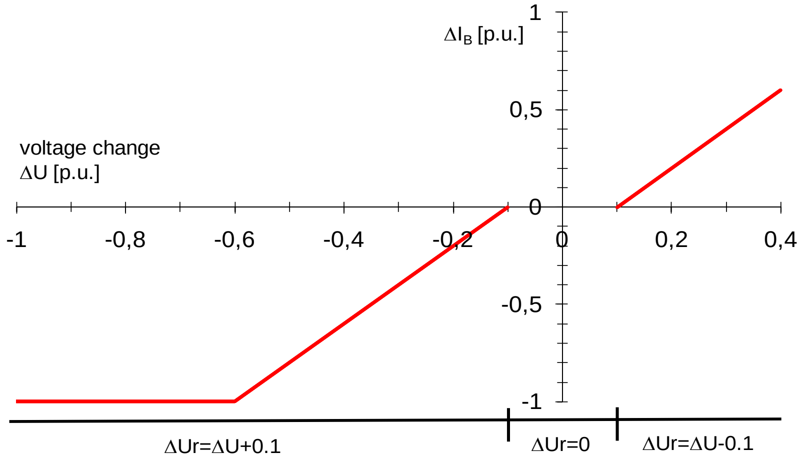
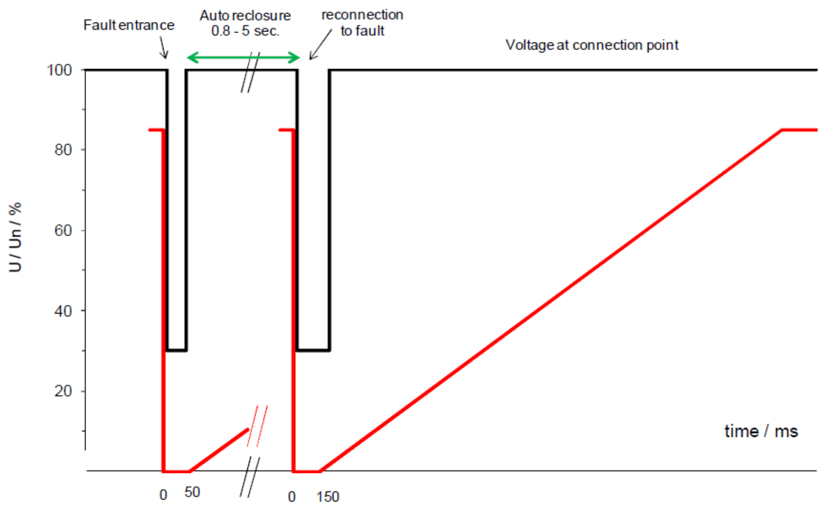
Odd harmonics	Distortion limits
3rd through 9th	< 4.0 %
11th through 15th	< 2.0 %
17th through 21st	< 1.5 %
23rd through 33rd	< 0.6 %

Even harmonics	Distortion limits
2nd through 8th	< 1.0 %
10th through 32nd	< 0.5 %

19	Total harmonic current distortion *It specifies the total harmonic current distortion*	✓	✓	Numerical [%]
	Example[3]: (Small scale PV installation at low voltage 0.38kV) *Total harmonic current distortion shall be less than 5 % at rated generator output in accordance with IEC 61727:2004.*		✓	Numerical [%]
3.3.2 Flicker		✓	✓	Text
20	Short term flicker (Pst)	✓	✓	Numerical [p.u.]
21	Long term flicker (Plt)	✓	✓	Numerical [p.u.]
	Example[2]: *Short term (10 minutes):* *Pst ≤ 0.35* *Long term (2 hours):* *Plt ≤ 0.25*	✓		[p.u.]
3.3.3 Voltage		✓	✓	Text
22	Voltage unbalance *Voltage unbalance at PCC is defined as the deviation between the highest and lowest line voltage divided by the average line voltage of three phases.*	✓	✓	Numerical [%]
23	Voltage fluctuations *The voltage fluctuations at PCC due to:* *- capacitors switching operations,* *- wind turbine generator start/stop,* *- inrush currents during wind turbine generator starting, etc.*	✓		Numerical [%]
3.4 Active power control				

24	Active power Output versus Frequency *It is the output power control of the Wind Farm/PV Plant due to grid frequency change at PCC.*	✓	✓	Figure, Table
	Example[2]: *Requirements on the output power of the Wind Farm in case of grid frequency and grid voltage variations.*  	✓		Figure
25	Active power control due to over-frequency *It is the reduction rate of Wind Farm/PV Plant due to grid over-frequency event at PCC.*	✓	✓	Figure, Table
	Example[2]: *Rate of Wind Farm's output power reduction due to grid over-frequency event.*  	✓		Figure
3.5 Reactive power control		✓		Text
26	Reactive power control *The steady-state reactive power capability shall be specified in a PQ-chart.*	✓		Figure, Table
	Example[2]: *It is the Wind Farm reactive power control based on its P-Q diagram.*	✓		Figure

				
27	Voltage versus reactive power capability chart	✓		Figure
3.6 Synchronization Requirements		✓	✓	Text
28	Synchronization Requirements *These requirements at PCC shall be stated, such as:* - *frequency difference;* - *voltage difference between phases; and* - *phase angle difference.*	✓	✓	Text, Numerical
3.7 Temporary Voltage Drop *Wind turbine/PV Plant is not allowed to disconnect from the Grid in case of short voltage drops due to grid faults under a pre-specified period of time.*		✓	✓	Text
29	Fault Ride Through (FRT) *It is the capability of the Wind Farm/PV Plant to withstand short voltage drops due to grid faults while not being disconnected from the grid.* *Information regarding general description, such as statistics of number and type of grid faults should be stated.*	✓	✓	Figure
	Eample[2]: *Wind Farm FRT* 	✓		Figure
30	Current injection during the fault	✓		Figure
	Eample[2]: *Wind Farm allowable current injection during faults.*	✓		Figure

				
31	Temporary voltage drops due to a non-successful auto-reclosure	✓		Figure
	Example[2]: It is the permissible number of non-successful auto-reclosure at PCC. 	✓		Figure
3.8 Wind Farm/PV Plant's System and relay protection		✓	✓	Text
32	Description *General description of the Wind Farm/PV Plant under study.*	✓	✓	Text
33	Protection Type *The Wind Farm/PV Plant shall or may trip dependent upon the setting requirements, such as:* - *Under frequency protection;* - *Over frequency protection;* - *Under Voltage protection;* - *Over voltage protection;* - *etc…*	✓	✓	Numerical [p.u.]
34	Islanding with load *This parameter specifies requirements in relation to potential situations where a Wind Farm/PV Plant may island with consumer loads connected.*	✓	✓	Text

3. REAL-TIME DATA PROCESSING		RES Technology		Unit
		Wind	PV	
Real Time Data Measuring and Monitoring *General description shall be included to descript the measuring and controlling aims.*		✓	✓	Text
35	Date of issuing/implementation *It is the information related the Wind Farm/PV Plant at PCC to be transferred for management purposes, such information are:* - *Technical measured values;* - *Status signals from the Wind Farm/PV Plant; and* - *Set-point values, given from the Grid Operator to the Wind Farm/PV Plant.*	✓	✓	Text
36	Real Time Control *Network's operator shall be able to submit control signals to the common control system of the Wind Farm/PV Plant to be followed.*	✓	✓	Text

Chapter Three: The Current Status in the Arab Region

In order to investigate the readiness of the Arab countries to integrate RES projects into the electricity networks, a survey has been conducted in order to gain insights into the existing and the foreseen technical readiness/maturity of electricity networks in Arab countries. First a questionnaire has addressed the general information about the grid codes and the associated RES codes, and then it gets into further details to figure out the level of contribution of the RES plants in the static and dynamic performance of the grids. Further, it assesses the status of the grid in terms of the needed reinforcements, interconnection projects, and introduction of smart applications. This chapter of the report aims to summarize the findings of the countries' responses to the questionnaire, as well as the literature review that is publically available in this regard.

3.1. Grid Codes

Some of the Arab countries have grid codes; however few have codes for RES plants.

Replies - as well as literature review - show that most of the Arab countries have codes for the transmission and distribution networks. Full implementation of these technical codes ensures that they do reflect the ongoing practice for managing the grids. For that reason as well, it is important to ensure that the codes are being periodically updated to match the changes that the grids might encounter. In KSA, the grid code committee meets quarterly to review and votes on modifications or amendments. In Egypt, the grid code development committee is responsible for deciding on any updates or derogation of the code.

3.2. RES Codes

Very few of the Arab countries have codes for Wind or PV

- In spite of the fact that most of the Arab countries have ambitious RES targets to fulfill by 2020 (some have extended it to 2030), yet very few are in the process of developing these codes, and fewer are having them in place.
- Also, replies show that although some countries have on going RES projects, they request no specific standards for connecting or operating the plants. Other countries just opt for international standards. The reason behind could be that the level of penetration of RES project in most of the countries are still modest, so that they don't really impact the management or the operation of the grids. However, in few years this will not be the situation.
- An example of countries that have RES codes is Egypt, where there are codes for Wind, small scale PV (below 500 kW), and utility scale PV which is under development. Since the small scale PV code sets requirements for projects which are connected to the low voltage network, thus it drafted such that it is as simple as ensures the safe operation of the low voltage grid, and to maintain the grid's protection and performance requirements to the levels that existed before connecting these projects.

- In KSA, the grid code is amended with clauses to accommodate the integration of Wind and PV plants. KSA reply denoted that such clauses are compared to the international codes of countries that have similar grid topology. These comparisons are even included in the grid code amendments. In Lebanon, a different approach if followed where the Danish code is used as a reference in their bid for wind projects.

3.3. Connection of RES projects and Contribution to Grid Performance

- Wind projects in the Arab region are utility scale ones that exist in Egypt, Morocco, and Tunisia, in addition to few projects ranging from 0.5 to 4.5 MW in Bahrain, Lebanon, Jordan and Mauritania. On the other hand, most of the countries have PV projects with capacities of few megawatts; the largest of them is in UAE of capacity 33 MW. Many projects are currently under development; the largest is in Egypt with total capacity of 2000MW.
- Replies show that the utility scale RES projects are connected to the 66 KV networks and above; according to the topology and the technical requirements of the grids. Generally, replies didn't show specific capacity limits that should be considered in deciding the voltage level of connection, except for Egypt. In Egypt, projects below 500kW are connected to the low voltage network (below 11 kV), projects ranging from 500kW till 20MW are connected to the medium voltage network(11kV, 22KV), from 20 MW till 100 MW are connected to the high voltage network(66 kV), above 100 MW is connected to the extra high voltage network (220kV).
- Some countries denoted that smart grid applications (e.g, advance metering infrastructure "AMI", advanced operation distribution "ADO", and advanced transmission operation "ATO") are in place. These ensure the readiness of these grids towards integration of RES projects.
- In term of contribution to the grid performance, replies show that in some countries – KSA as an example - RES plants may respond to frequency control upon request form the system operator, while in Egypt RES plants are requested to commit to the frequency ranges defined in the relevant codes. Other requirements like active and reactive power control and fault ride through shows to be rather similar.
- Most of the responses show that for power quality requirements including harmonics, flicker, voltage unbalance, and fluctuations, the international standards are followed.

مبنى المحطات المائية (الدور ٧)
بلوك ١١ - قطعة ١٥ عمارات ملسا
أرض الجولف، مدينة نصر، القاهرة، مصر
الهاتف: +٢٠ ٢ ٢٤١٥ ٤٧٥٥
الفاكس: +٢٠ ٢ ٢٤١٥ ٤٦٦١

Hydro Power Building (7th Floor)
Block 11 - Piece 15, Melsa District
Ard El Golf, Nasr City, Cairo, Egypt
Telephone: +20 2 2415 4755
Fax: +20 2 2415 4661

www.rcreee.org