USING HARMONIZED EUROPE NETWORK CODE AS A BENCHMARK FOR COMPATIBILITY TESTING OF AUSTRALIA AND IRAN GRID CODES

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ABSTRACT

This paper uses harmonized Europe network code known as EU-code as a benchmark for compatibility test of Australia and Iran grid codes. Australia and Iran are selected as two non-Europe countries with different levels of distributed generation (DG) penetration and technical issues for compatibility testing of their grid codes with EU-code. Both countries have issued their new version of grid codes in 2014. The paper compares some selected codes including active power, reactive power and Fault Ride Through (FRT) of mentioned countries with EU-code. The European code is approved by Agency for the Cooperation of Energy Regulators (ACER) of Europe in 2014, too. The results of paper can be used in Australia and Iran for compatibility test of their grid codes with EU-code. The paper focuses on possibility, advantages and disadvantages of each country's grid code to follow EU-code. The proposed procedure of paper might be extended to other countries, too.

INTRODUCTION

In 2013, global renewable electricity generation reached nearly 5070 TWh and accounted for almost 22% of total power generation worldwide. Rapidly increasing of penetration of renewable electricity generation has been one of the main reasons for revising the existing grid codes in different countries. A grid code is a technical specification which defines the parameters of an electrical power generation system in such a way that it’s safe, secure and economic operation is guaranteed. Grid codes are documents that define rules and principles for connecting all types of generators (including wind turbines) to the interconnected grid. Grid code of utility should meet its technical requirements. Grid codes are essential for grid operators, wind power producers, wind power developers and equipment suppliers.
Performance compatibility of electrical equipment like different types of wind turbines (such as DFIG and PMSG based), converters, transformers and switchgears with grid codes have to be analysed and tested. As an example for analysing purpose, the DigSilent software has developed its grid code which has model validation possibility according to some countries’ grid codes like Australia. For test purpose, the ABB has developed a multi-megawatt laboratory for examination of grid code compatibility tests like the ramping of active power of DGs at start-up after a disconnection. Of course, the mentioned laboratory has testing facilities in high power ratings for fault ride-through purpose, too. Obviously, analysing (or simulation) based methods for grid code verification are cheaper than test based methods but, they don't represent real behaviour of studied electrical equipment.
On the other hand, diversity of technical requirements results in different grid codes in utilities. Usually grid codes' requirements in a utility are based on renewable energy penetration level, power system stability and power quality constraints, governmental policies toward renewable energies and local utility practices. This is the reason for dissimilar grid codes in different utilities of different countries.

Diversity of grid codes from international point of view may result in following disadvantages:

1) It is not possible to share, collaborate and exchange the scientific knowledge easily and confidently.
2) Different grid codes result in different standards, operation procedure and specifications of equipment.
3) Moving toward renewable energy in developing countries is usually based on imported products from different countries. Therefore, different standards will result in coordination problems in their utility.

Harmonized Europe network code may be considered as the most important challenge for harmonizing different grid codes in a continental level [1]. Most of countries in Europe had high level of renewable energy penetration in addition to developed national grid codes; so, modifying the existing codes would be a serious engineering and legislation attempt. While there exist some doubts in successfulness of recently approved version of EU-code, it is the sole sample of international grid code in the world [2, 3].
The EU-code might be used as a benchmark for other countries to test their grid code compatibility. Extension of EU-code to non-European countries could be beneficial from international points of view. By considering doubtless role of Europe in worldwide electrical industry, this new harmonized code may affect the other countries’ grid code, too. Non-European countries may benefit from compatibility of their national grid code with EU-code from technical and economical points of view. Obviously, current technical situation of each country’s electrical utility such as penetration level of distributed generation units (DGs), results in different strategies for compatibility testing of national grid codes with EU-code.
This paper focuses on some of the key technical

requirements in Australia and Iran grid codes to test their compatibility with EU-code. The proposed methodology should be extended to all technical requirements of mentioned grid codes to find out the necessary modifications and its advantages and disadvantages. Also, the proposed strategy might be implemented for other countries to achieve a wider spread international grid code.

HARMONIZED EUROPE NETWORK CODE

Harmonised Europe network code that is known as ENTSO-E network code, can be considered as an important experience and challenge to harmonize different national grid codes. The European code (EU-code) which will provide new opportunities for European countries is recently approved by Agency for the Cooperation of Energy Regulators (ACER) of Europe in 2014. The EU-code has divided the power generation modules (PGMs) into four category known as A, B, C and D and has defined the power and voltage thresholds of them. The rating thresholds for PGM type A is the smallest while it is highest for type D.
The European grid code will be supranational and will prevail over the European nations ones regarding cross-border issues. Of course, European nation's grid codes will remain valid in those parts that do not concern cross-border issues. European grid codes will provide some “parameters” while the European nation's grid codes can provide the strict requirements.

AUSTRALIA NETWORK CONNECTION CODE

Australia is a progressed country in the field of renewable and has carried out some revision of its national network connection rules during recent years. Renewable energy resources generate 5.6 % of total energy with average annual growth of 11.5% in 2012-13 [4]. Australian Energy Market Commission (AEMC) has published “Network Connection, Planning and Expansion” as chapter 5 of “National Electricity Rules Version 63” while it's commenced date was 1 July 2014 [5]. These rules provide the connection requirements for generating plant to a transmission or a distribution network and access to the national grid. The connected plant should not adversely affect power system security or the power quality of supply to other grid users. Based on technical requirements, the network connection rules have subdivided the generating plants into following three kinds:

a) Automatic access standard,
b) Minimum access standard,
c) Negotiated access standard.

This division is not based on power or voltage rating of generating system. A generating system will be categorized in one of the mentioned access standards if it meets all the standard requirements of that access.

IRAN UTILITY CONNECTION RULES FOR DISTRIBUTED GENERATORS

Iran is in its first steps of developing DGs but tries to fill its gap with progressed countries in a short and reasonable time scope. Iran has issued a set of distributed generation (DG) oriented grid codes in 2014. These new grid codes guarantee protection of utility rather than DG systems. It explains the connection rules of just Gas Engine (GE) and Gas Turbine (GT) based DG units. The mentioned grid code refers to ANSI and IEEE standards, if necessary. Iran grid code doesn’t guarantees the protection of DG, itself and it has excluded Asynchronous generators and solar photovoltaic systems in this stage [6].

COMPARISON OF EU, AUSTRALIA AND IRAN GRID CODES

This section provides a comparison between EU, Australia and Iran grid codes for following technical requirements:

a) Active Power Controllability (APC),
b) Reactive Power Capability (RPC),
c) Fault Ride Through (FRT).

While more than 20 items should be compared for a complete compatibility test between mentioned grid codes, these three requirements are selected to explain the compatibility test procedure for compared grid codes.

Active Power Controllability (APC)

Active power controllability defines the technical requirement for active power control of a generating unit. Table I shows a bridged APC requirements of EU-code for different types of PGMs. All types of PGMs need facilities to exchanging information with relevant Network Operator (NO) and/or the relevant Transmission System Operator (TSO). The necessary active power control capability of each PGM type is instructed by relevant NO/TSO. This table shows that by increasing the power rating of PGMs from type A to type D, the technical APC's requirements increase. While it is enough to provide active power cease capability for PGM type A, the set point shall be capable to be adjusted by instruction of NO or TSO for type C and D.

Table I. The APC requirements in EU-code

Generator type	A	B	C	D
Active power Control type	Ceasing (less than 5 seconds)	Reduction	Adjusting	

Australia network connection rules for Automatic access standard units says that, for 30 [MW] or more, linearly adjusting of active power is necessary with related dispatch instructions. These rules for Minimum access standards say that, for 30 [MW] or more, linearly reduction of active power within 5 minutes is necessary for non-scheduled generating system with its dispatch instructions. For details, it is necessary to refer to related documents.

According to Iran grid code, for safety reasons, the distributed generation units (DGs) should not deliver electrical energy to an un-energised distribution network. Also, the generated active power of DGs should not result in violation of permissible frequency and voltage magnitude of utility.

Reactive Power Capability (RPC)

Reactive power capability defines the technical requirement for reactive power control of a generating unit.

In EU-code there is no special RPC requirement available for type A and B. For type C Synchronous PGM (SPGM), the relevant TSO shall define the related RPC with regard to RPC at maximum capacity by considering the following requirements:

The U-Q/Pmax-profile shall not exceed the U-Q/Pmax-profile envelope, represented by the inner envelope in figure 1. Response time shall be defined by relevant NO.

The position of the U-Q/Pmax-profile envelope within the limits of the fixed outer envelope in figure 1 could be violated. It means the position of inner envelope can move inside the outer envelope and it should be decided by TSO/NO. Table II is in relation with figure 1 and defines the maximum range of Q/Pmax and steady state voltage level in per-unit.

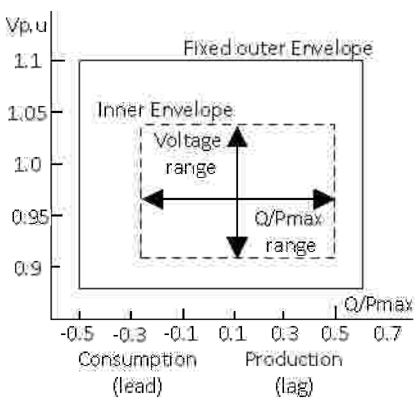

Fig. 1. The U-Q/Pmax-profile for type C SPGM in EU-code

Table II. The maximum ranges of variables in fig. 1

Synchronous Area	Maximum range of Q/P_{max}	Maximum range of steady state voltage level in PU
SPGM	0.95	0.225
PPM	0.75	0.225

The PRC requirements for Power Park Module (PPM) that is a generation unit that connects to utility through a power electronic converter in type C is similar to figure 1 but with the values of last row of table II. Also, for the RPC of generator type C, PPM in EU-code we have the following rules:

Reactive power shall be provided automatically by either voltage control mode, reactive power control mode or power factor control mode. In voltage control mode, the PPM shall cover a voltage set point change at least 0.95 to 1.05 [pu] and slope range of 2 to 7 %. Following a step change in voltage, the PPM shall be capable of achieving 90% of the change in reactive power output within a time in the range of 1 - 5 [s]. Settling time on target value is 5-60 [s] with lower than 5% steady-state tolerance.

Australia grid code requires automatic access standard wind power plants to provide capacitive reactive current of at least 4% of their maximum continuous current for each 1% reduction in the voltage of interest, when the voltage drops to less than 90% of its rated value. This means that wind farms must generate their maximum reactive current when the voltage of interest reduces by more than 25%. No capabilities are required for minimum access and negotiate-access standard generating units to supply or absorb reactive power.

According to the RPC of Iran grid code, the reactive power exchange of DGs with utility should not affect the voltage regulation of utility adversely. In other words, the automatic Voltage Regulator (AVR) of DGs should not provide any negatively effect on voltage regulation of utility. The RPC of Iran grid code just focuses on reactive power affect on voltage regulation of utility during its normal operation.

Fault Ride Through (FRT)

The FRT is a technical requirement for keeping the electrical energy generating units connected to grid during faults. By FRT, it is possible to avoid resynchronization problems and delay. In addition, the generating unit will improve stability of power system during fault conditions.

Table III shows the FRT requirements in EU-code for different types of generating units. Fig. 2 shows a schematic representation of FRT requirements in EU-code. The FRT capability of generating units is mandatory in EU-code and is one of the essential requirements for EU grid code.

Table III. The LVRT requirements in EU-Code. Voltages are in [pu] and time is in [sec.]

Generator type	B or C	
PGM	SPGM	PPM
U_{ret}	0.05-0.3	0.05-0.15
t_{Clear}	0.14 – 0.25	
U_{Clear}	0.7 – 0.9	U_{ret} – 0.15
t_{rec1}	t_{Clear}	
$U_{rec}1$	U_{Clear}	

$t_{rec\,2}$	$t_{rec\,1} – 0.7$	$t_{rec\,1}$
U_{rec2}	0.85 – 0.9 and = U_{Clear}	0.85
$t_{rec\,3}$	1.5 – 3.0	

Generator type	D	
PGM	SPGM	PPM
U_{ret}	0	0
t_{Clear}	0.14 – 0.25	
U_{Clear}	0.25	U_{ret}
t_{rec1}	$t_{Clear} – 0.45$	t_{Clear}
$U_{rec}1$	0.5 – 0.7	U_{Clear}
t_{rec2}	$t_{rec\,1} – 0.7$	t_{rec1}
U_{rec2}	0.85 – 0.9	0.85
t_{rec3}	$t_{rec\,2} – 1.5$	1.5 – 3.0

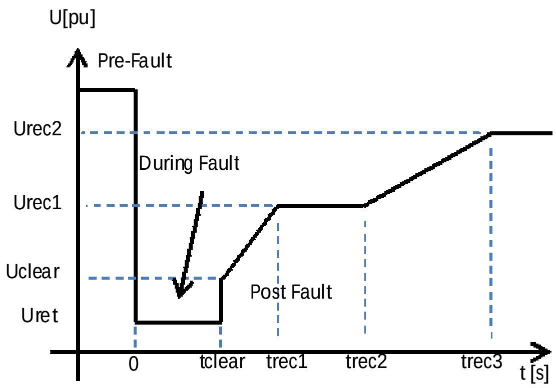

Fig. 2. The FRT diagram of EU code

Australia has different FRT requirements for automatic access, minimum access and negotiated access standard generation units. The strictest rules are applied to automatic access standard and include the following main items:

- Capacitive reactive current must be provided of at least 4% of maximum continuous current for each 1% reduction from pre-fault level of connection point voltage during fault.
- The PGM should remain uninterrupted for following transmission faults:

  Three-phase Line to Line (LLL) transmission fault until cleared by breaker fail protection system. For Line to Line to Ground (LLG), LL and LG the rules are like LLL unless, if protection system is not installed, the values of table IV should be used. If none is specified, it will remain connected to grid for at least 430 [ms].

The PGM should remain uninterrupted for following distribution faults:
The LLL, LLG, LL and LG until cleared by breaker fail protection system. If protection system is not installed, the greater of 430 [ms] (which is the longest time expected) is to be taken for all relevant primary protection system to clear the fault.

Table IV. Voltage at fault location vs. time

Vn at fault location [kV]	Time [ms]
Vn = 400	175
250=Vn<400	250
100<Vn<250	430
Vn = 100	As necessary to prevent plant and meet stability

The FRT requirements for minimum automatic access standard and negotiate access standard are different than automatic access standard but are easier to be followed.
Australian grid code requires wind power plants to restore their active power output to 95% of the pre-fault value within 100 ms after the fault clearance. The Australian grid codes has one of the most stringent requirements in this regard, which can be justified by their weakly interconnected power networks, that demands for fast active power restoration in order to maintain the network frequency stability.
Iran grid code doesn’t apply any FRT capability for renewable energies and it is just enough for a generating unit to remain connected until fault be cleared by breaker protection system.

COMPARISON OF APC, RPC AND FRT IN AUSTRALIA AND IRAN GRID CODES WITH EU-CODE

Comparison of APC rules for Australia and Iran grid codes with EU-code shows that in EU-code relevant Network Operator (NO) and/or the relevant Transmission System Operator (TSO) have obligating for determination of exact control parameters while Australia and Iran grid codes have clear requirements without referring to local utility operators. Also, the APC requirements in EU-code are in more detail in comparison with Australia and Iran grid codes. Iran grid code has simplest rules on APC of DGs. It seems EU-code for APC could be used in Australia and Iran as a benchmark and both grid codes have potential to be modified in this regard. Any modification in Iran grid code might be easier than Australia.
The RPC for EU-code, Australia and Iran is mainly focused on voltage regulation. It seems the RPC requirement for EU-code has inherent potential to be used as a benchmark for some modification in Australia and Iran grid codes to bring them closer to EU-code.
The FRT in EU-code is strongly different from Australia and Iran grid codes requirements. The Australia and Iran grid codes are very different in terms of FRT requirements, too. It seems the FRT might be considered

as one of the last items to be modified in compared grid codes.

CONCLUSION

This paper compared some selected technical requirements of Australia and Iran grid codes with EU-code. These requirements include Active Power Controllability (APC), Reactive Power Capability (RPC) and Fault Ride Through (FRT). All three grid codes had some rules on mentioned technical issues. While EU-code has more detail requirements for APC and RPC, it could be used as a benchmark for modification of Australia and Iran grid codes to make them more compatible with EU-code. The FRT requirements of three grid codes are considerably different, but it is still possible to use the EU-code in this regard. Overall, it seems, Iran has better chance to make its grid codes more compatible with last progresses in EU-code in comparison with Australia. It is because of less developed DGs in Iran which results to less economical costs and technical efforts in comparison with Australia.

It should be noticed that any modification in a grid code needs a comprehensive study of overall technical requirements. More collaboration is necessary between working groups in international level. Also, it should be mentioned that EU-code is in its first steps and it needs to be progressed toward a more harmonized grid code by itself.

REFERENCES

[1] "ENTSO-E Network Code for Requirements for Grid Connection Applicable to all Generators", 8 March 2013.

[2] L. Rouco, K. Chan, J. Oesterheld, S. Keller, "Recent Evolution of European Grid Code Requirements and its Impact on Turbogenerator Design", IEEE Power and Energy Society General Meeting, 22-26 July, 2012.

[3] L. Aleixo, M. D. Catrinu, D. E. Nordgard, T. Preda, "Possible impacts of the new ENTSO-E network code on Distribution Power Systems in Norway", IEEE PowerTechConf., 2013.

[4] Australian government, Bureau of resources and energy economics, July 2014

[5] Australia "National Electricity Rules", Version 63, Chapter 5, Network Connection, Planning and Expansion, published on 1 July 2014, pp. 371-593.

[6] The Guideline for Connection of Distributed Generators to Utility, Ver. 1, Jan. 2014, Tavanir, Iran.