Explanatory note to the Italy North TSOs proposal for a common D-2 capacity calculation in accordance with Article 21 of Commission Regulation (EU) 2015/1222 of 24 July 2015 establishing a guideline on capacity allocation and congestion management

May 2018

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1 Introduction

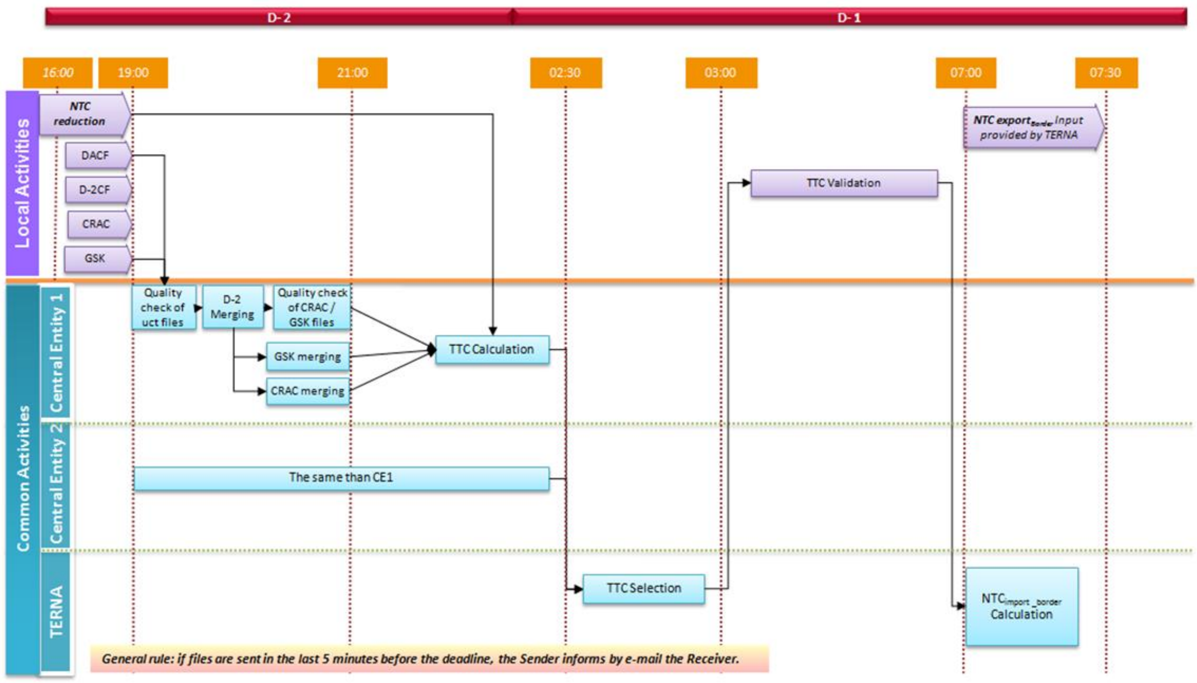
This technical document sets out the main principles for the coordinated capacity calculation methodology for the day-ahead market timeframe applied in Italy North region. It contains a description of both the methodology and the calculation process in compliance with the Capacity Allocation and Congestion Management guideline (hereafter CACM).

The participating TSOs for this calculation are TERNA (IT), RTE (FR), Swissgrid (CH), APG (AT) and ELES (SI), following borders are considered Italy – France, Italy – Switzerland, Italy – Austria, and Italy – Slovenia.

2 DA Capacity Calculation Approach

This document describes coordinated NTC approach to determine the cross-border capacities for each border of the Italy North (IN) CCR. The NTC of each border are calculated in two scenarios, one with Italy importing from all the borders of the Region at the same time and one with Italy exporting to all the borders of the Region at the same time.

The DA Capacity Calculation process is composed of several sub-processes as shown on the process scheme below. Each sub process is associated to a role and linked with all the other sub processes that depends on it.



The process starts with a data gathering sub-process, followed by quality control & merging sub-process, capacity calculation (optimization) sub-process, validation and finally NTC calculation sub-process. The full description of the whole process and its sub-processes is presented in the following chapters.

3 Italy's import direction

3.1 Capacity calculation input

3.1.1 Transmission Reliability Margin (TRM)

3.1.1.1 General principles

The Reliability Margin can be modelled as a probability distribution function resulting from taking into account two variables:

- uncertainties of the forecast between D-2 capacity calculation studies and real time,
- unintended deviations on the whole Northern Italian Interconnection.

Therefore, the RM probability distribution function can be obtained by the convolution of the two probability distribution functions corresponding to the described variables (TRM_1 for the uncertainties of the forecast and TRM_2 for the unintended deviations).

The TRM refers to the whole Northern Italian Interconnection.

The TRM shall be calculated every year for the next year. Until the TRM will not be calculated according to this methodology, the TRM value is equal to 500 MW.

Uncertainties in TTC computation

The Coordinated NTC calculation methodology is based on different inputs provided by TSOs, they are based on best available forecast at the time of the capacity calculation for RES, consumption, production plans or available network elements and those could differ from the real-time situation. Differences between forecasts and real time situations may lead to insecure TTCs given to the markets endangering the security of supply.

Unintended load-frequency regulation deviations

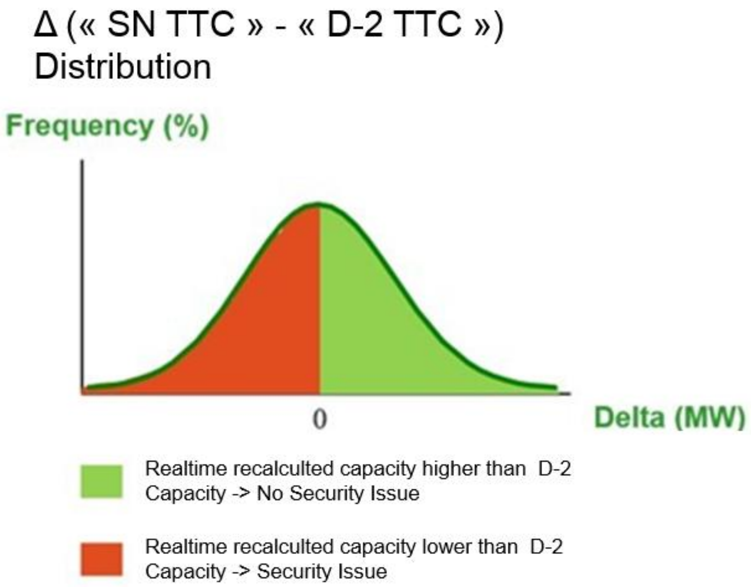
For control-related reasons, in an AC interconnected system, deviations continuously occur between the scheduled exchange values and the actual physical flows between neighbouring control areas. This implies that at any moment the physical exchange between two control areas can be significantly higher than the scheduled exchange, endangering the security of supply.

3.1.1.2 TRM figure computation

The process for the TRM_1 determination could be described as follows:

- step 1: define the statistical period: one full year.
- step 2: discard the timestamps (TSs) of the statistical period not useful for the study (e.g. TS where no capacity calculation has been performed, TS with the capacity limited by Additional Constraint, etc.). Also, TSs for which the TTC have been calculated via extrapolation have to be selected.
- step 3: retrieve the following data for all the selected TS:
  - o D-2 TTC without UTTC or LTTC cap/floor ("TTC D-2"),
  - o the Real time CGM for the selected TS,

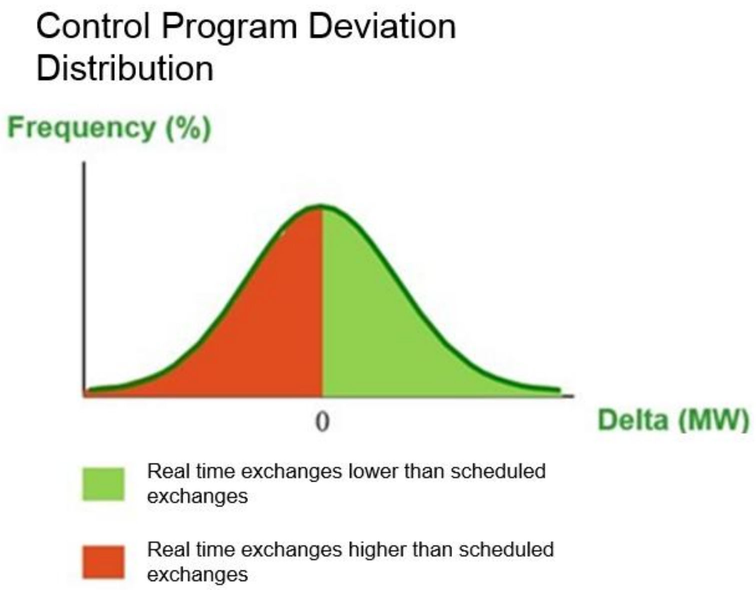
  - o the D-2 CGM of the capacity calculation for the selected TS,
  - o reduced Splitting factors.
- step 4: compute the TTC ("TTC RT") on the real time CGM selected after step 3 for all the selected TS. Then compute all the deltas "TTC RT" – "TTC D-2" and plot those deltas in a distribution curve.



TRM_1= uncertainties of the forecast

The process for the TRM_2 determination could be described as follows:

- step 1: define the statistical period: one full year.
- step 2: for the statistical period retrieve the control program error for the Italian control area (difference between the scheduled program and the actual physical exchange at the Northern Italian interconnection). One minute average values could be used.
- Step 3: plot those deltas in a distribution curve:



TRM_2= unintended deviation

Once TRM_1 and TRM_2 distribution functions have been calculated the TRM distribution function can be calculated:

$$TRM = \text{convolution}\ (TRM_1, TRM_2)$$

The TRM shall be defined as the 99 percentile of the convolution of the probability distribution functions of the two variables TRM_1 and TRM_2.

3.1.2 Operational security limits, contingencies and allocation constraints

Operational security limits, contingencies and allocation constraints in capacity calculation on Italy North are provided daily by all TSOs of the Italy North region in form of the critical outage list, list of critical network elements and additional allocation constraints.

The critical Outage (CO) list describes the contingencies to be assessed during capacity calculation. A contingency can be a trip of a line, a cable or a transformer or a set of the aforementioned contingencies. This list, called “reference outages”, contains all Italian interconnectors as well as internal lines of the 5 TSOs which are affected with Italian import and is predefined and agreed among the participating TSOs; however, the list can be updated as soon as it is required and agreed among the participating TSOs.

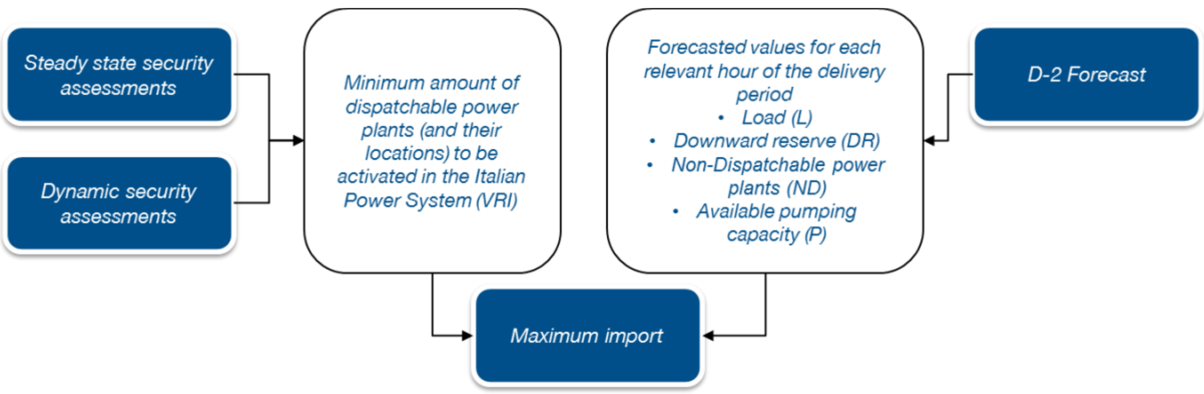
Critical network element (CNE) is a network element either within a bidding zone or between bidding zones taken into account in the capacity calculation process, limiting the amount of power that can be exchanged. Each participating TSO is required to provide a list of critical network elements (CNEs) of its own control area based on operational experience as well as operational security limits. A critical network element can be an interconnector, an internal line or a transformer. The operational security limits used in the common capacity calculation are the same as those used in operational security analysis. CNEs are independently and individually associated with relevant outages. Additionally, for each CNE for each outage, zero or more remedial actions that relieve the CNE is/are defined. As the selection of monitored elements might have an impact on the total calculated capacity, it is defined that CNE can only be an element that is consistent with the real time security rules and at the same time its loading is significantly impacted by the Italian import.

For that, at the beginning of the process, TSOs have to create an initial list of CNEs for each calculated timestamp. There will be a so-called “selection” of CNEs, based on sensitivity of exchange, in order to avoid that pre-congested grid elements whose loading is almost not influenced by cross borders exchanges could limit the exchanges at the Italian Northern Border. For the moment, this methodology is not yet implemented, but under testing phase, with a sensitivity equal to 5%. According to the initial experimentation, it is expected that this threshold will ensure all important critical elements are included, and also ensure the exclusion of elements not impacted by the Italy North import. At the end of this experimentation phase the TSOs will have the possibility to reassess the sensitivity threshold. TSOs have the possibility to add a specific CNE if it is sensitive in a particular situation but would not be detected by the pre-processing with an ex-post justification.

In case there is any CNE whose power flow is influenced by cross-zonal power exchanges in a different Capacity Calculation Region, before including it in the Capacity Calculation process, the TSOs have to define rules for sharing the power flow capability of the CNE among the different Capacity Calculation Regions in order to accommodate this flow.

Allocation constraints are typically used to take into account additional security constraints that cannot be expressed with CO/CNE combinations. In the Italy North CCR, such constraints are typically referred as “Special Periods”. They are currently defined by the Italian TSO and shared with the other TSOs and CCC as a maximum value of acceptable import at the whole Northern Italian Interconnection in order to cope with operational security constraints related to voltage control and dynamic system stability. These two kinds of constraints are needed to maintain the transmission system within secure operations but cannot be translated efficiently in form of maximum flows on critical network elements. Furthermore, they require additional data and more complex calculations, which shall be adapted to cover specific and different cases. When the additional constraint is applied, the TTC will be no higher than the value TTCmax, at the end of the calculation.

The procedure applied by the Italian TSO is described in the following chart:



In particular, during low demand/high renewable infeed periods, the Italian Power System has to be properly managed in order to avoid:

- Voltages above the operational security limits;
- Low system inertia;
- Dynamic instability.

Hence, a minimum amount of dispatchable power plants able to provide system services according to the criteria of System Operation Guidelines (eg. voltage regulation, primary reserve, …) has to be activated.

This minimum set of power plants is quantified performing:

- Weekly steady-state security assessments;
- Dynamic assessments on several scenarios considered representative of the expected system conditions.

Once this minimum set of power plants is defined, the maximum amount of import at the Northern Italian Border for each market time unit is computed considering demand and generation forecast available in D-2: the scope is to make the Italian TSO able to activate the needed set of power plants, applying redispatching actions at national level. This maximum amount is computed according to the following formula:

$$Import_{max}^{h} = [L^{h} - DR^{h}] - [ND^{h} + VRI^{h}] + P^{h}$$

Where:

- *L: hourly load forecast*
- *DR: downward reserve defined according to the uncertainties related to load and RES forecasts*
- *ND: infeed expected from non-dispatchable power plants*
- *VRI: is the infeed from the minimum set of dispatchable power plants*
- *P: available pumping capacity*

All the data above is included in a so called “individual CRAC” file of each TSO. Prior to calculation, individual CRAC files of all TSOs are merged.

3.1.3 Generation and Load Shift Keys (GLSK)

GSK file is defined for:

- an area
- a time interval: GSK is dedicated to individual daily hours in order to model differences between peak and off-peak conditions per TSO.

Generation and Load shift keys are needed to transform any change in the balance of control area into a change of injections in the nodes of that control area. In order to avoid newly formed unrealistic congestions caused by the process of generation shift, TSOs define both generation shift key (GSK) and load shift key (LSK), where GSKs constitute a list specifying those generators that shall contribute to the shift and LSKs constitute a list specifying those load that shall contribute to the shift in order to take into account the contribution of generators connected to lower voltage levels (implicitly contained in the load figures of the nodes connected to the 220 and 400 kV grid). Each TSO can decide how to represent its best generation shift.

If GSK and LSK are defined, a participation factor is also given:

- G(a) Participation factor for generation nodes
- L(a) Participation factor for load nodes

The sum of G(a) and L(a) for each area has to be to 1 (i.e. 100%).

Definition of GSK and LSK Nodes:

The list of GSK nodes contains one or more node defined by:

- the name of UCTE Node
- the maximum power production of the node > (optional for prop and fact, mandatory for the other methods)
- the minimum power production of the node (optional for prop and fact, mandatory for the other methods)

Several methods are supported by the process:

- **Proportional**:

Shift in defined generation/load nodes, proportionally to the base case generation/load.

- Pg(n) Active generation in node n, belonging to area a (nodes n defined in GSK list or
- Pl(n) Active load in node n, belonging to area a (nodes n defined in LSK list)

The participation of node n in the shift, among selected gen. nodes (GSK) is given by:

$$Kg(n,a) = G(a) \cdot \frac{Pg(n)}{\sum_n Pg(n)}$$

The participation of node n in the shift, among selected load nodes (LSK) is given by:

$$Kl(n,a) = L(a) \cdot \frac{Pl(n)}{\sum_n Pl(n)}$$

- **Participation factors**:

Shift in defined generation/load nodes (PV or PQ nodes), according to the participation factors:

- kg(n) Participation factor for generation in node n, belonging to area a
- kl(n) Participation factor for load in node n, belonging to area a

The participation of node n in the shift, among selected gen. nodes (GSK) is given by:

$$Kg(n,a) = G(a) \cdot \frac{kg(n)}{\sum_n kg(n)}; 0 \leq kg(n) \leq 10$$

The participation of node n in the shift, among selected load nodes (LSK) is given by:

$$Kl(n,a) = L(a) \cdot \frac{kl(n)}{\sum_n kl(n)};\ 0 \leq kl(n) \leq 10$$

- **Reserve**:

All power plants, which are chosen for the shift, are modified proportionally to the remaining available capacity, as presented hereafter in these equations (1) and (2).

$$P_i^{inc} = P_i + \Delta E.\frac{P_i^{max} - P_i}{\sum_{i=1}^{n}(P_i^{max} - P_i)} \quad (1)$$

$$P_i^{dec} = P_i + \Delta E.\frac{P_i^{min} - P_i}{\sum_{i=1}^{n}(P_i^{min} - P_i)} \quad (2)$$

Where:

P_i = Actual power production.

P_i^{min} = Minimal power production.

P_i^{max} = Maximal power production.

ΔE = Power to be shifted.

P_i^{inc} = New power production after positive shift.

P_i^{dec} = New power production after negative shift.

- **Merit order**

The chosen generation nodes shift up or down according to the correspondent merit order list GSKup or GSKdown, as described following:

- upward list contains the generation nodes which performs the total positive shift.
- downward list contains the generation nodes which performs the total negative shift.

Merit order factor defines the number of generation node to be shifted simultaneously.

It means that the first group (number defined with Merit order factor) of generating nodes are shifted together and if it is not sufficient, the next group generating nodes are used to complete the total shift, and so on.

The total shift is distributed to the last group of Merit order factor generation nodes proportionally to their available margin as defined for Reserve shift.

Generation shift keys in Italy North region are determined by each TSO individually on the basis of the latest available information about the generating units and loads.

3.1.4 Remedial Actions

The term “Remedial action” refers to any measure applied in due time by a TSO in order to fulfil the n-1 security principle of the transmission power system regarding power flows and voltage constraints. Capacity calculation in Italy North region uses two types of remedial actions:

- Preventive Remedial Actions (PRAs) are those launched to anticipate a need that may occur, due to the lack of certainty to cope efficiently and in due time with the resulting constraints once they have occurred.
- Curative Remedial Actions (CRAs) are those needed to cope with and to relieve rapidly constraints with an implementation delay of time for full effectiveness compatible with the Temporary Admissible Transmission Loading. They are implemented after the occurrence of the contingencies.

Preventive and curative actions in Italy North region may be declared as shared or declared to be used only locally by TSO.

All types of remedial actions can be used in preventive and/or curative state.

Only SPS (Special Protection Schemes) will act in curative stage, after tripping of grid elements.

SPS refers to special protection scheme application that automatically applies remedial actions in the grid (for example line disconnection) if predefined set of conditions is fulfilled (for example if outage of parallel line occurs). The SPS protection equipment is located in the relevant substations and reacts within several seconds. For lines equipped with SPS, three loadings have to be checked compared to just two for typical N-1 states: the one directly after outage (typically around 140 %), one after application of automatic remedial actions by the SPS (typically 120 %) and current after application of all other remedial actions (typically 100 %).

Remedial actions are defined by each TSO of the region daily as a part of individual CRAC file. Each remedial action has a pre-agreed name so other TSOs can refer to it. The remedial actions are used by CC if they have a positive impact on capacity of import of Italy. New preventive remedial actions can be added by a TSO in its daily CRAC file and some others can be removed depending on the forecasted situation.

Each TSO within the Italy North Region shall coordinate with the other TSOs of the Region regarding the use of remedial actions to be taken into account in capacity calculation and their actual application in real time operation.

Each TSO shall ensure that remedial actions are taken into account in capacity calculation under the condition that the available remedial actions remaining after calculation, taken together with the reliability margin referred to in Article 5, are sufficient to ensure operational security.
The use, during the real time, of remedial actions defined during capacity calculation process will be described in the implementation of security analysis according to the SO GL Article 75 and 76.
Preventive Remedial Actions are implemented in the final CGM of the capacity calculation. Their application in during later operational security timeframes (DACF, IDCF and real time) is evaluated based on the Security Analysis taking into account the latest grid information.

Example:
Let assume the activation of the preventive remedial action, 2 nodes in Substation A, during the D2CC to relieve congestions on axis A-B.

In real time, due to other market situation, the violation is not monitored by the TSO X, most probably, the opening of the busbar coupler will not be performed, in order to avoid loss of meshing of the grid. But, in case this violation really occurs in Real Time, then the remedial action will be activated and implemented.

3.1.5 Creation of Common Grid Model

Common grid model (CGM) used for capacity calculation represents expected state of ENTSO-E interconnected grid for selected timeframe. CGM is obtained with merging of individual grid models (IGMs) provided by the TSOs.

All TSOs of the region are obliged to provide D-2 IGMs for selected timestamps (currently 12 timestamps per day) prior to the calculation. The D-2 IGMs (known also as D2CF) have to contain the following information:

- Best estimation for:
  - the planned grid outages;
  - the outages of generating units and the expected output power of the running generating units;
  - the forecasted load pattern;
  - the forecasted RES generation.
- Have the balance compliant with a reference day balance on the day-ahead reference Website (Vulcanus).

For TSOs outside Italy North region, D2CFs are typically not available; therefore, their DACF files are used instead.

Once all IGMs are available, the merging entity starts the process of merging them into CGM. If non-participating TSO’s inputs are missing, a predefined back-up procedure is applied replacing the missing IGMs with the most appropriate alternative ones. If any D2CF by a TSO of the region is missing, merging process is interrupted immediately, as replacing an IGM of a TSO of the region with one of an older topology can have a significant influence on power flow distribution and as consequence on performed security analysis results.

The merging process itself is split into the following sub-processes:

- Data pre-treatment (each participating IGM is checked for compliance with the rules, check of convergence and balance);
- Building of control blocks corresponding to the day-ahead reference Website data;
- Balance adjustment on control blocks or TSOs;
- Merging of the ENTSOE wide data set;
- Final balance adjustment of the ENTSOE data set.

The result of merging process is a common grid model used for capacity calculation in the Italy North region.

3.2 Capacity Calculation Methodology

Each Coordinating Capacity Calculator (CCC) performs, for each timestamp, a capacity assessment to calculate the TTC_{total} by combining the inputs and applying the capacity calculation methodology as detailed in the next chapters.

3.2.1 General principles

The Total Transfer Capacity (TTC_{total}) for the whole northern Italian border is assessed using the following principles:

- based on the merged D-2 and DACF grid models;
- all calculations are performed using Alternate Current (AC) load-flow algorithm, considering reactive power capability limits of generators;
- Italian import maximization is divided into multiple steps (latter described in the dichotomy approach section); for each step Italian import is increased more until maximum import is found;
- the modification of exchanges is realized according to GSKs and Splitting $Factor_{Border}$ (which take into account the impact of planned outages near a specific border, assessed through NTC reductions);
- the maximum current for the network security of Critical Network Elements is respected (taking into account effects of remedial actions used);
- being not higher than the additional constraint (corresponding to low consumption periods);
- aiming at maximizing the TTC_{total} by respecting the above-mentioned constraints, especially by combining efficiently the given Remedial Actions.
- optimization of remedial actions is performed using combination of heuristic search and linear optimization

3.2.2 Principles to perform the Generation Shift

- For any modification of total import on the northern Italian border, the modification of balance shall be shared among TSOs according to splitting factors.
- Exchanges through some particular lines are kept constant and equal to predetermined values given by the TSOs. Are considered as particular lines the following:
  - Lines not represented in the grid model, whose flows are conventionally considered as fixed;
  - Those of the Merchant lines which are operated at a fixed flow during real time for operational reasons.
- When during the calculation a GSK is exhausted (cannot provide additional shift), then a load redistribution is allowed to continue the calculation (based on the load of the related country).
- For all types of GSK except MERIT ORDER, in case, some generating nodes are reaching their maximum or the minimum limitations, this node is set to P_{max} or P_{min}. The rest of the power to be shifted in the CGM should be distributed to the other nodes being contained in the GSK files, without taking into account the node which is at the saturation.

The mathematical formulation is the following one, where:

- ***Exchange*** represents commercial exchanges. Therefore, they include all exchanges to be transmitted through the grid, either TSO-owned or merchant lines;

- ***ExchangeTSO*** represents the part of exchanges that will be transmitted through TSO-owned grid (as opposed to merchant lines);
- ***ExchangeML*** represents the part of exchanges that will be transmitted through merchant lines;
- $_{Border}$ index stands for one of the four north Italy borders: **CH-IT**, **FR-IT**, **AT-IT**, and **SI-IT**;
- ^{ref} index refers to quantities from the reference day, implemented in the merged ***CGM.***

For each border we have by definition the identity:

$$\mathit{Exchange}_{Border} = \mathit{ExchangeTSO}_{Border} + \mathit{ExchangeML}_{Border}$$

During TTC calculation, only ***ExchangeTSO*** shall vary, for each border, according to ***Reduced Splitting Factors***.

$$\mathit{ExchangeTSO}_{Border} = \mathit{Reduced\ Splitting\ Factor}_{Border} \,.\, \mathit{ExchangeTSO}_{North\ Italy}$$

$$\Delta \mathit{Exchange}_{Border} = \Delta \mathit{ExchangeTSO}_{Border} = \mathit{ExchangeTSO}_{Border} - \mathit{ExchangeTSO}^{ref}_{Border}$$

$$\Delta \mathit{Balance}_{TSO} = \sum_{TSO\ Borders} \Delta \mathit{Exchange}_{Border}$$

Variations are applied on the merged CGM for which exchanges values are given by the reference day values. **Exchanges through ML are assumed equal to their daily Fixed Flow provided as input data.**

$$\mathit{ExchangeTSO}^{ref}_{Border} = \mathit{Exchange}^{ref}_{Border} - \sum_{Border} \mathit{Fixed\ Flow}_{ML}$$

Summary

This may be summarized as:

$$\Delta \mathit{Balance}_{TSO} = \sum_{TSO\ Borders} \mathit{Reduced\ Splitting\ Factor}_{Border} \,.\, \mathit{ExchangeTSO}_{North\ Italy} - \mathit{ExchangeTSO}^{ref}_{Border}$$

$\Delta \mathit{Balance}_{TSO}$ shall be implemented from the initial merged CGM, according to GSK handling rules, for each participating TSO. Generation shift handling is described below.

The formulas below are used to calculate the Italian import applied in the model to assess the grid security. The initial model already contains schedules of a reference day. In order to modify the Italian import, it is required to adjust the net positions of FR, CH, AT, SI and IT. the adjustment of the net positions is done with the help of the formulas below.

For each country, this translates into:

$$\Delta \mathit{Balance}_{FR} = \mathit{Reduced\ Splitting\ Factor}_{FR>IT} \,.\, \mathit{ExchangeTSO}_{North\ Italy} - \mathit{ExchangeTSO}^{ref}_{FR>IT}$$

$$\Delta \mathit{Balance}_{CH} = \mathit{Reduced\ Splitting\ Factor}_{CH>IT} \,.\, \mathit{ExchangeTSO}_{North\ Italy} - \mathit{ExchangeTSO}^{ref}_{CH>IT}$$

$$\Delta \mathit{Balance}_{AT} = \mathit{Reduced\ Splitting\ Factor}_{AT>IT} \,.\, \mathit{ExchangeTSO}_{North\ Italy} - \mathit{ExchangeTSO}^{ref}_{AT>IT}$$

$$\Delta \mathit{Balance}_{SI} = \mathit{Reduced\ Splitting\ Factor}_{SI>IT} \,.\, \mathit{ExchangeTSO}_{North\ Italy} - \mathit{ExchangeTSO}^{ref}_{SI>IT}$$

$$\Delta Balance_{IT} = -\Delta Balance_{FR\text{-}IT} - \Delta Balance_{CH\text{-}IT} - \Delta Balance_{AT\text{-}IT} - \Delta Balance_{SI\text{-}IT}$$

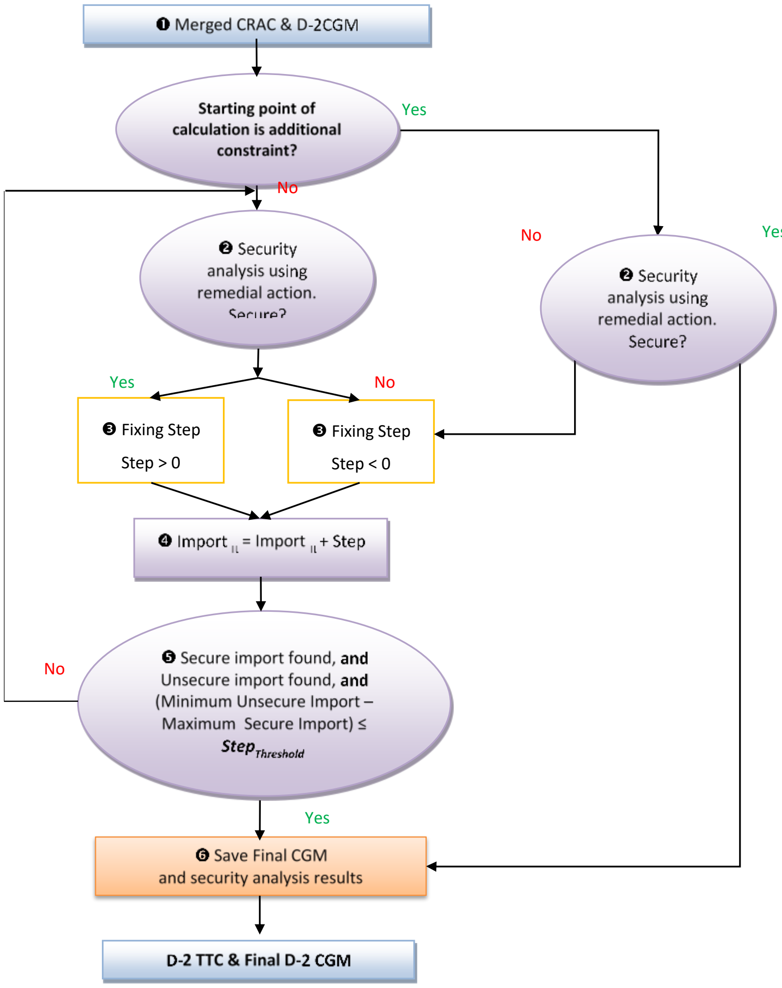
Concretely, the import level used inside the calculation to check the grid security is splitted to all borders according to the ***Reduced Splitting Factor*** in order to know what the schedules would be, if the calculation would be over at this import level. In the initial merged model, reference schedules ***ExchangeTSO***^{ref} are already present inside this one. It means to know how much the model should be shifted inside the model to reach this import level, the difference between the hypothetical schedules and the initial schedules should be performed.

Example with an expected TTC of 8000 MW:

	FR-IT	CH-IT	AT-IT	SLO-IT
Reduced Splitting Factor	0.35	0.5	0.05	0.1
Schedules for 8000 MW	2800	4000	400	800
ExchangeTSO^{ref}	2000	3000	200	500
ΔBalance	800	1000	200	300

3.2.3 Dichotomy approach

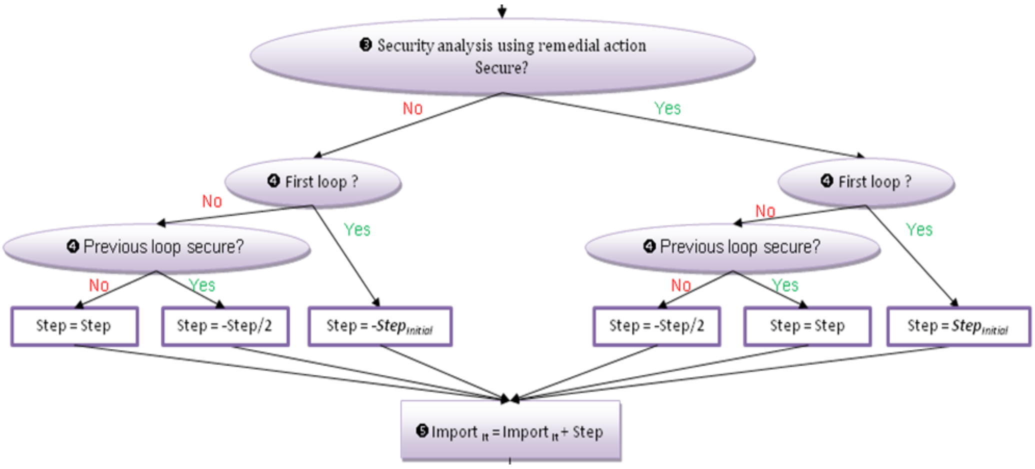
The capacity calculation step can be described as a calculation by dichotomy. The CCC will define a starting capacity level and check if this level of exchange allows the transmission system to be operated within its operational security limits.



Starting capacity level is based on reduced yearly value of TTC (i.e. yearly calculated value reduced for capacity of planned outages) as well as the additional constraint provided by Terna in its CRAC file. The minimum value between the two values is chosen as starting point for the calculation.

If the level is secure or can be made secure by optimizing remedial action as described in 3.2.4, it will then test a higher value of TTC. Otherwise the coordinated capacity calculator will then test a TTC value in between the secure and unsecure TTC values until it reaches the last secure TTC. Stopping criteria for optimization is finding last secure and first unsecure level of import. Once both are found, last secure import is considered as maximum Italian import.

The dichotomy is set with a 50 MW step in order to optimize the capacity offered to the market while reducing the computation time. Considering optimal remedial actions have been applied in each step of capacity calculation, the dichotomy approach guaranties final solution is less than 50 MW suboptimal compared to absolute maximum Italian import.



3.2.4 Handling of Remedial Actions

The scheme below summarizes the conditions to be fulfilled with this combination of remedial actions to state that all security constraints are respected. Each rounded square represents a different network state.

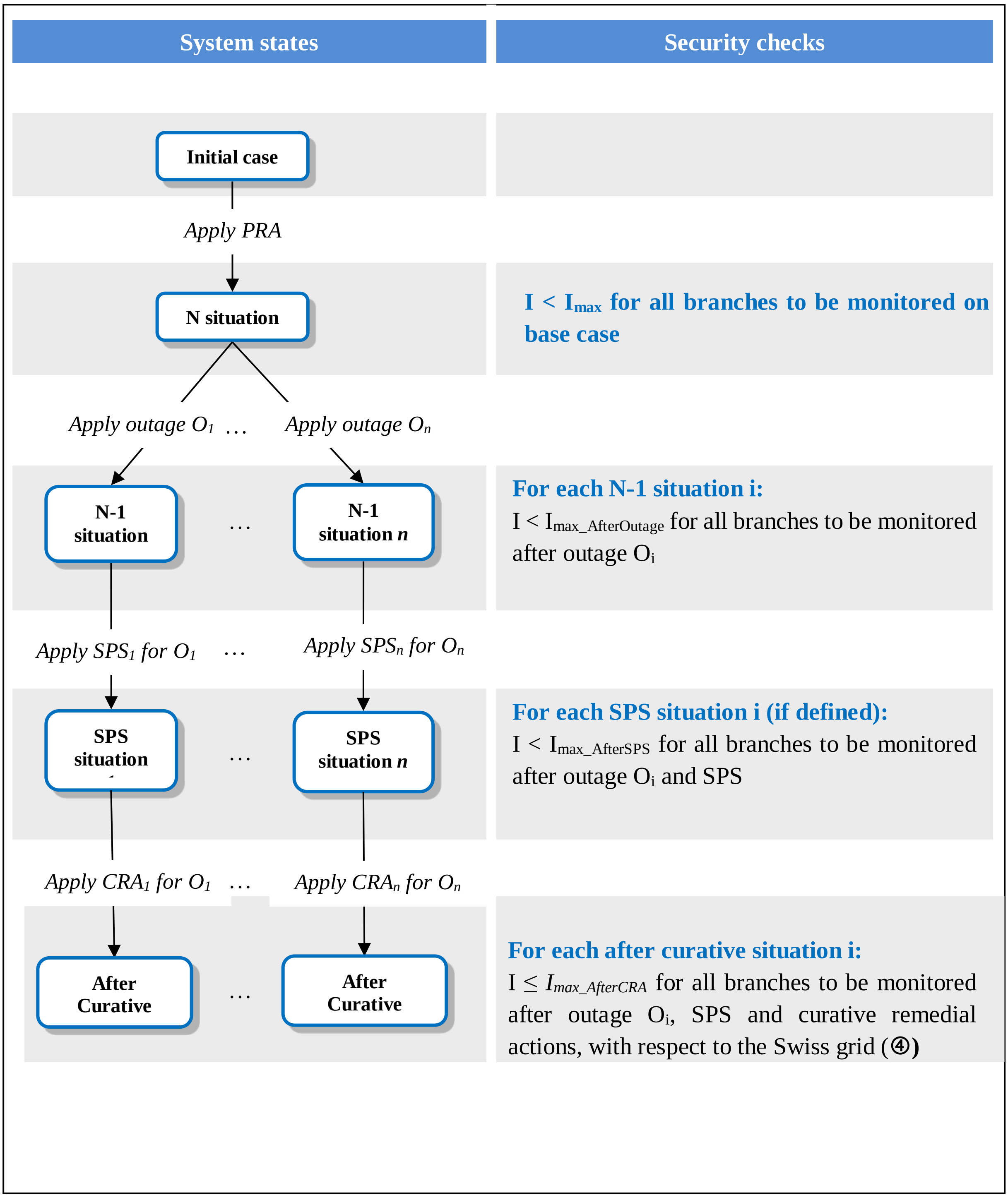
On N state, preventive remedial actions are implemented and Imax of "base case" branches are monitored.

On N-1 states, outages are applied and Imax_AfterOutage are monitored. They represent transient admissible current on the monitored branches. Transient current can exceed permanent admissible current provided that available SPS and curative remedial actions are sufficient to keep permanent current not greater than permanent admissible current.

On After Curative states, outage, SPS and curative remedial actions are implemented and Imax_AfterCRA are monitored. They represent permanent admissible current on the monitored branches.

If an outage or a remedial action leads to an unbalance situation due to a modification of generation or load pattern, this unbalance has to be compensated inside the concerned country, by using the GSK of this one.

On SPS states, outage and SPS are applied, Imax_AfterSPS are monitored. Imax_AfterSPS represent transient admissible current on the monitored branches after SPS. Transient current can exceed permanent admissible current, provided that available curative remedial actions are sufficient to keep permanent current not greater than permanent admissible.



3.2.5 Extrapolation algorithm

This chapter describes how the TTC is calculated for those timestamps for which no direct calculation is performed during the transitory period in which only few timestamps will be taken into account as references for the whole day.

For each hour H, be Href the reference hour for TTC calculation (i.e. if 10:30 is the only studied timestamp for the period 07:00-23:00, Href=10:30 for all the hours h in the interval 07:00-23:00). The

TTC value for hour H is calculated according to the following table depending on the "type" of hours H and Href:

		H_{ref}	
		LC/Ramp	**No LC**
H	**LC**	$TTC_H=\min(TTC_{Href}+\Delta TTC_{P,H\text{-}Href}, AC_H)$	$TTC_H=\min(TTC_{Href}, AC_H)$
	Ramp	$TTC_H=\min(\max(TTC_{P,Hi}, TTC_{Href}), AC_H)$ Where $H_i \in$ (interval with the same H_{ref})	$TTC_H=\min(TTC_{Href}, AC_H)$
	No LC	$TTC_H=\min(\max(TTC_{P,Hi}, TTC_{Href}), AC_H)$ Where $H_i \in$ (interval with the same H_{ref})	$TTC_H=\min(TTC_{Href}+\Delta TTC_{P,H\text{-}Href}, AC_H)$

Where:

- Type "No LC" means that the hour is in a normal period, without Low Consumption NTC;
- Type "LC" means that the hour is in a Low Consumption period;
- Type "Ramp" means that the hour is in a ramp period (e.g. connecting Low Consumption NTC to Normal NTC);
- TTCHref is the Selected TTCTTC selection Total North, the selected TTC of the reference hour Href as described in the HLBP;
- TTCP,Hi is the scheduled TTC (the TTC defined in the programming stage taking into account all the reductions for planned maintenances and low consumption period) of the generic hour Hi which has Href as reference hour;
- ΔTTCP,H-Href = TTCP,H - TTCP,Href;
- ACH is the Additional Constraint defined for hour H.

3.2.6 Results

For each Coordinating Capacity Calculator and each timestamp, the set of results is:

- The initial (merged) grid model and the final (merged) grid model corresponding to the final state of the network for a maximum secured northern Italian import. In this final state, all preventive ("pre-fault") Remedial Actions are implemented;

- Concatenated GSKs, a concatenated CRAC files containing Critical Network Elements, Critical Outages, and Remedial Actions and additional constraint (maximum value of TTC_{total});

- TTC_{total};

- Limiting elements of TTC_{total} (Critical Network Elements and Critical Outages). In case the calculation stops to an import level equal to the additional constraint, there is no limiting element (the reason of limiting TTC_{total} is the additional constraint itself), otherwise limiting elements always exist;

- results of security analysis with preventive and curative Remedial Actions.

3.3 Methodology for TTC Selection

The transition from the practices based on daily NTC to the one based on the outcome of the D-2 calculation process requires attention in terms of security, costs and transparency.

The final compatibility of the outcomes of D-2 calculations with the abovementioned requirements has to be assessed progressively on the base of the experience, by comparing and analysing daily values with values from the D-2 process.

Even though this process is not explicitly foreseen in CACM Regulation, TSOs consider it a necessary step to avoid unreasonably low or unreasonably high capacities as a result of automatic process. A limiting band is considered necessary until the real operation proves that forecast evaluations are sustainable. To prove the sustainability this band has to be broaden gradually till the full stabilization of the D-2 process. The band is limited by two values, the Upper Total Transfer Capacity (UTTC) and Lower Total Transfer Capacity (LTTC).

The UTTC limit is used to prevent unreasonably high calculated Italian import. The reasons for this might be incorrect input data (for example missing some critical monitored elements or outages) or serious bugs in the process of Coordinated Capacity Calculator.

The LTTC limit is used to ensure that calculated TTC is not too low. During the experimentation period it was observed some calculated Italian import capacities are extremely low because of different issues in input data (for example overloaded radially connected elements, improper GSKs, insufficient voltage support, etc.) or serious flaws in the process of Coordinated Capacity Calculator. As calculated TTCs cannot be increased during validation process, it is vital to increase them beforehand. During the validation process, TTC can be decreased again if considered so by the party performing validation.

The use of limits is an interim solution; it is planned the TSOs of Italy North Region will use the UTTC and LTTC limit in the selection process until the intraday capacity calculation covering the 24 hours of the day will be in service.

3.3.1 Definition of the basic parameters

With the aforementioned rationale the selection criteria are described in the following.

Definitions:

i is the index of the observation period

j is the index of the generic TTC value resulting from the calculations of the Coordinated Capacity Calculator

h is the hour of the day to which the timestamps refer. (e.g. at present h=**p** means peak hours h=**o** means off peak hours).

T_i is the i^{th} observation period, being T_0 the last 3 months of the same season.

$TTC_{j,h}$ is the TTC value resulting from the calculations of the Coordinated Capacity Calculator referring to hour h.

$RTTC_h$ Is the yearly TTC value reduced to take into account maintenances and low consumption periods

$UTTC_{i,h}$ is the upper limit of the TTC for the period T_i and hour h. $TTC_{i,h}$ greater than this upper limit are considered not credible reasons of violation could be wrong input data or serious bugs in the process of Coordinated Capacity Calculator.

$LTTC_{i,h}$ is the lower limit of the TTC for the period T_i and hour h. Below this limit the results are considered not credible for the same reasons as described above.

$Iss_{i,h}$ is the significant set of statistical samples of **$TTC_{j,h}$** showing consistency of results of the Coordinated Capacity Calculator in a given period of observation T_i. $Iss_{i,h}$ does not include cases:

- where:
  - days are affected by additional constraints (e.g. low consumption days)
  - data are affected by errors in individual grid models
- Coordinated Capacity Calculators fail the calculation process
- one Coordinated Capacity Calculator is below LTTC and the other over the UTTC in case of two Coordinated Capacity Calculators perform the TTC Calculation,
- referring to days when the real time emergency procedures have been applied (for upper limits only) [1] and the Italia import has been reduced for security reasons.

$Iss_{i,h}+$ is the subset of **$Iss_{i,h}$** including the samples **greater than UTTC** only

δh_{i+} is the mean value of the samples resulting from Max (0; **$Iss_{i,h}+$ - $RTTC_h$**) in a given observation period T_i respectively for

δh_{i-} is the mean value of the samples resulting from Max (0; **$RTTC_h$ - $Iss_{i,h}-$**) in a given observation period T_i

$$\boxed{UTTC_{i,h} = RTTC_h + \delta h_{i+}}$$

[1] For lower limits days when the real time emergency procedures were applied have to be included and the TTC = TTC- reduction amount due to real time emergency procedures

$$LTTC_{i,h} = RTTC_h - \delta h_{i-}$$

The above-mentioned set of parameters will be processed for each additional timestamp adopted in the future in the capacity calculation process.

3.3.2 Selection procedure

Figure 1 depicts the criterion with the following comments.

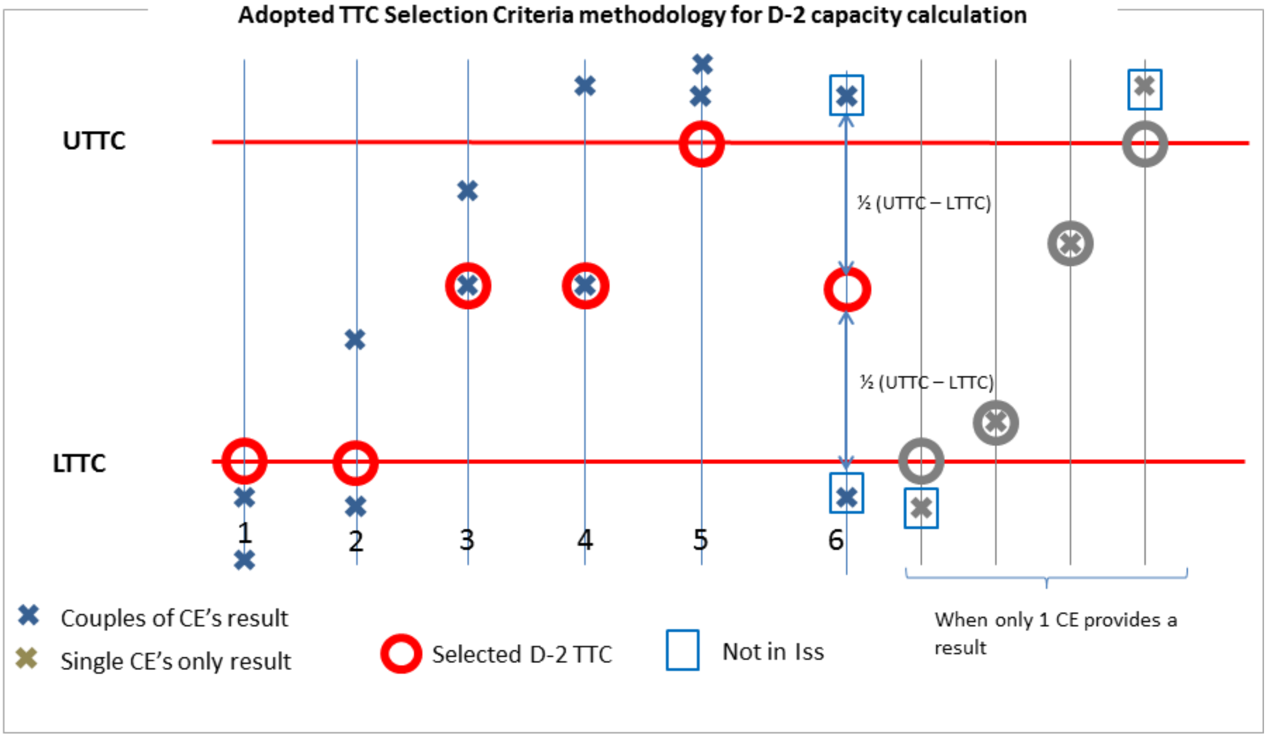


Figure 1

- In case of two Coordinated Capacity Calculators provide valid results, if the couple of $TTC_{j,h}$ lies inside the plausibility band UTTC – LTTC, then the selected value has to be the lowest between the two outcomes.
- In case of two Coordinated Capacity Calculators provide valid results, if the couple of $TTC_{j,h}$ lies outside the band and both on the same side, selected value will be the closest band limit. In this case the a priori diagnosis is that something went wrong with input data. More careful validation is required.
- In case of two Coordinated Capacity Calculators provide valid results, with one outcome is over the upper limit and the other is under the lower limit, the selected value will be shifted at the

center of the band. In this case the a priori diagnosis is that something went wrong with the calculations but both results have 50% of probability to be correct. Also, in this case the validation has to be intensified and operators are allowed to propose increases of the validated TTC.

- In case of outcomes delivered by just one Coordinated Capacity Calculator, the comparison is skipped and according to the confidence on the process the values inside the band are supposed valid.

3.3.3 Initial calculation (winter Period)

Please note that the daily TTC in days w/o lines out of services (i.e. the annual TTC) has been taken into account. This because the daily values are variable and it would be necessary to have a maximum for each possible topology.

This is considered acceptable because the final goal is to find plausible values.

In addition to that:

- UTTC values have been calculated including days w/o maintenance and including in the Iss+ the values above the yearly TTC
- LTTC values including all the rest of the days.

Please note that some refinements are expected to be necessary in the future for the following reasons:

a) The number of samples turned out to be limited from the statistical point of view
b) A reason why there are differences against annual values deserve to be further analysed. In particular with regard to:
    a. The influence of Remedial Actions
    b. The influence of monitored elements
c) Define set of parameters with and without planned outages.

3.3.3.1 Peak Hour Values [MW]

PEAK summer and winter

- UTTC = daily + 600 MW
- LTTC = daily – 500 MW

3.3.3.2 Off peak values [MW]

OFF PEAK summer

- UTTC = daily + 600 MW
- LTTC = daily - 500 MW

OFF PEAK winter

- UTTC = daily + 500 MW
- LTTC = daily - 500 MW

3.3.4 Band broadening

The band ***i+1*** is calculated at the end of each season (summer/winter).

Before calculating the band ***i+1***, an observation period must be completed and some parameters must be respected in order to ensure that the data used for the calculation guarantee a sufficient degree of representativeness (i.e. if the calculated NTCs have almost never been fully used by markets it's not possible to state the calculations were reliable enough). For that, the following condition must be respected:

- $\mathbf{N_H}\geq 240$[2] and $\mathbf{N_D}\geq 20$: as soon as an observation period with the application of the band ***i*** is completed, they are evaluated:
    a. the number of hours ($\mathbf{N_H}$) for which $\mathbf{UTTC_{i-1,\,h}} < \mathbf{S_h} < \mathbf{UTTC_{i,\,h}}$ and no import curtailment has been applied and no ATC reduction has been needed. $\mathbf{S_h}$ is the total schedule of Italy.
    b. the number of days ($\mathbf{N_D}$) during which at least in one hour $\mathbf{UTTC_{i-1,\,h}} < \mathbf{S_h} < \mathbf{UTTC_{i,\,h}}$ and no import curtailment has been applied and no ATC reduction has been needed. $\mathbf{S_h}$ is the total schedule of Italy.

In case of the conditions above are not met, the observation period is considered as not yet completed and the new band ***i+1*** is not calculated. The "observation period" will continue until both conditions are met and at this time the new band ***i+1*** will be calculated.

Then, the application of the new band ***i+1*** can be done only if the following additional conditions are met:

- The security of the grid is guaranteed with the former band ***i*** after an in-depth analysis of available remedial actions. The following security criteria must be full-filed:
    a. Remedial actions available during Capacity Calculation were also available during operational phases (DACF, IDCF, Real Time).
- Any security problem, which may have led to import curtailments or ATC reductions, has been properly investigated and its causes identified;
- Solutions have been defined and implemented for the identified causes.

If the security criteria are not yet fulfilled, the TSOs can adjust the values for the new band ***i+1***.

3.3.5 About the evolution of band broadening

Up to now, band has been broaden only once, from initial 500 MW for UTTC and -500 MW for LTTC for both peak and off-peak (summer and winter) to current values defined in 3.3.3.1 and 3.3.3.2.

The main reasons why there was no additional band broadening were linked to the non-fulfilment of the listed requirements:

- The remedial actions available during the Capacity Calculation timeframes are not always applicable during the real time operation
- The causes which may have led to import curtailments or ATC reductions have been identified in:
    - Grid's topology variations between D-2 and Real Time timeframe (i.e. unexpected line outages)

[2] This means the band has been used at least in 240 hours, which roughly correspond to 10 full days.

- Load and Generation patterns forecast errors. In particular external grid representation in terms of forecasted Net Positions
- Forecasting errors linked to NTC extrapolation for the hours where the calculation is not performed (only 8 hours on 24)

3.3.6 Band Fall back

The band fall back will be managed as follows:

- As soon as two import curtailments (not due to increases in the IDCC process) or two ATC reductions (ATC reduction will be taken into account until the IDCC V2 process will be in place) took place within a rolling time window of seven days, the current UTTC of the band ***i*** is restricted to the UTTC of former band ***i-1*** (LTTC is not changed). After 2 weeks without any import curtailment, the band ***i-1*** is enlarged again with the value of the band ***i.***

In case during an observation period of a band fall back the same conditions for band fall back are reached an additional fall back to the UTTC of the former band is triggered (from band ***i-k*** to band ***i-k-1***).

After 2 weeks without any import curtailment, the band ***i-k*** is enlarged again with the value of the band ***i.***

3.3.7 Control of the LTTC

Once the criteria for band broadening or fall back are met, the update of both the limits of the band (LTTC and UTTC) is triggered. On the other hand, those criteria are mainly designed to check that the band guarantees against unsecure NTC values due to the upper limit and there is no specific criterion to prevent from having unrealistic or unsecure "low" NTC values (LTTC could be too low or too high). For this reason, for the time being, the Fall Back to former values of the LTTC will be triggered by experts based on the experience and on the analyses of the results.

In case the LTTC value will prove to be systematically not appropriate, new ad-hoc criteria will be defined in order to calculate and adjust it.

The update process is described in Figure 2.

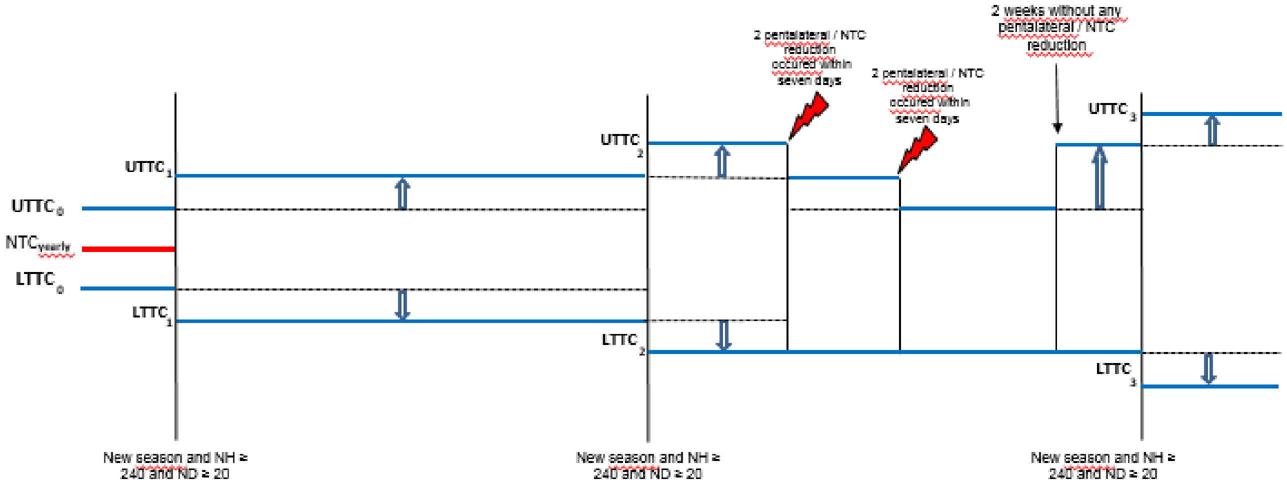


Figure 2

3.4 Methodology for the validation of cross-zonal capacity

Once the Coordinated Capacity Calculator has calculated the TTC, it provides the concerned TSOs with these values. Each TSO then has the opportunity to validate the TTC value calculated centrally or can reduce the value in case the centralized calculation failed to consider a particular constraint.

Those constraints could be, but not limited to, dynamic behaviour of the grid, unplanned outage that occurs after the deadline to update the inputs.

The TSO requesting a capacity reduction is required to provide a reason for this reduction, its location (all borders on only one border) and the amount of MW to be reduced in accordance with article 26.5 of CACM regulation.

Where several TSOs of a bidding zone border request a capacity reduction on their common border, TERNA will select the minimum value provided by the TSOs. The reason associated to this value will be the one taken into account in all report required by relevant legislation.

If there is an unplanned topology, e.g. one TSO is informed of an unplanned outage at 04:00 am. Coordinated capacity calculator does not have enough time to perform a recalculation but TSOs have time to take it into account in the validation phase and to analyse if a reduction in the capacity is needed.

For particular grid situations that occur not very often, some contingencies or critical network elements could be missing in the lists provided to the capacity calculator if these particular outages were not taking into account. In these cases, TSO could take into account those elements during the validation until the lists for the capacity calculator are updated by sending red flag with a new value of the TTC (justification of the reduction amount must be given on the border(s) concerned by the reduction).

In case TSOs expect different flow patterns as a result of different market situations compared to the assumption of the Capacity Calculation process, the TSOs shall assess and validate a secure capacity value

3.5 Methodology of bilateral splitting among borders

This part of the document describes the algorithm for the NTC calculation and its splitting. It also describes how the NTC is calculated for those timestamps for which no direct calculation is performed.

The final NTC values for each hour and each border are calculated following the steps described below:

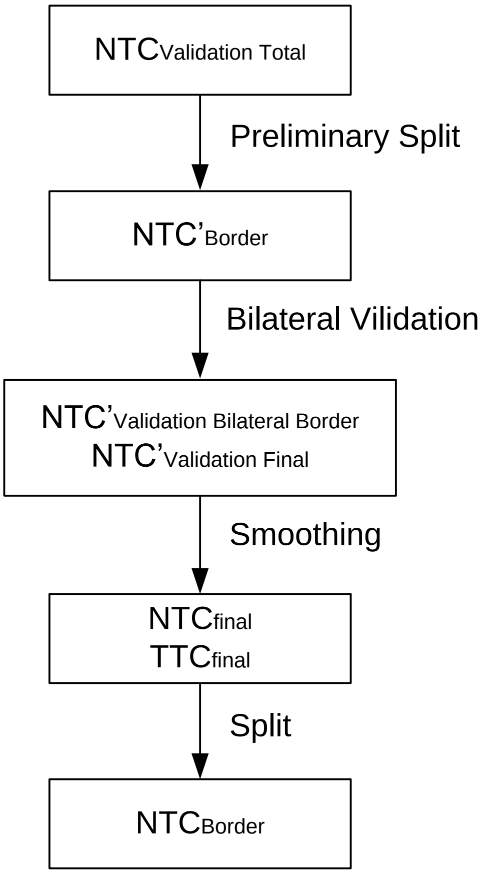


Figure 3 : NTC Calculation diagram

Preliminary NTC calculation

For each hour h, the Preliminary NTC is calculated from the result of TTC Selection, extrapolation included, and Validation on the total Northern Italian Border.

$$\mathbf{NTC_h = TTC_h - TRM}$$

Preliminary Split

The preliminary NTC is split between the borders taking into account the merchant lines on the North Italian Border and the splitting factors. The splitting factors are calculated according to the NTC values defined in the programming stage by the programming departments of the TSOs taking into account the NTC yearly values and the planned maintenances, which affect the security of the Italian import.

Bilateral Validation

For each hour, the preliminary NTC values are subject to the bilateral validation. If a TSO sends a lower bilateral NTC value than the previously calculated (red flag), this value is taken into account for the final NTC calculation. Then all bilateral NTC values in the respective hour are summed and the NTC profile throughout the 24 hours is smoothed, in order to avoid large variations between one hour and the next, as described below.

NTC profile smoothing

Large variations of NTC between one hour and the next may endanger the grid security during real time operations. For this reason, in line with the long and mid-term NTC planning, the NTC profile throughout the 24 hours has to be checked and possibly smoothed in order to respect the limits of maximum NTC increase or decrease in one hour defined by TERNA.

NTC values of the 24 hours (whether they are calculated or extrapolated from reference timestamps), coming from the bilateral validation process, are subject to the following iterative process:

1. Detect all hours h for which:
    - $NTC_{h+1} > NTC_h$ + Max_NTC_Stepupward
    - or $NTC_{h-1} > NT_{Ch}$ + Max_NTC_Stepdownward
2. Start analysing from the hour H, within those ones detected at point 1, with the minimum NTC
3. Step forward as long as NTCh+1 > NTCh + Max_NTC_Stepupward:
    - Set $NTC_{h+1} = NTC_h$ + Max_NTC_Stepupward
    - Step forward (h=h+1)
4. Step backward as long as $NTC_{h-1} > NTC_h$ + Max_NTC_Stepdownward
    - Set $NTC_{h-1} = NTC_h$ + Max_NTC_Stepdownward
    - Step backward (h=h-1)
5. Go back to step 1 (until no NTC value has to be changed)

The results of the smoothing process are the $\mathbf{NTC_{Final}}$ of each hour. The $\mathbf{TTC_{Final}}$ of each hour are calculated as:

$$\mathbf{TTC_{Final,h} = NTC_{Final,h} + TRM}$$

Final NTC splitting

The NTC after smoothing (NTC Final) is split between the borders taking into account the merchant lines on the North Italian Border and the splitting factors. The splitting factors take into account the possible bilateral red flags and the NTC values defined in the programming stage by the programming departments of the TSOs taking into account the NTC yearly values and the planned maintenances which affect the security of the Italian import.

3.6 Fall back procedure

At the beginning and during every D-2 process the availability of all necessary files is constantly checked. For files that are missing or do not respect the formatting rules, a manual or automatic replacement is performed. Manual communication is done via Phone and via E-Mail. Manual data exchange is done via the ECP or E-Mail. Any new file update should be communicated to the Coordinated Capacity Calculator in due time. In case the Coordinated Capacity Calculator receives a new file within the given timeframe, the calculation should be restarted. If a necessary file is not received in time and no replacement is possible or the calculation dose not succeed, the process is ended and reported as failed. In case of process failure, the commercial department will use the reduced yearly NTC.

4 Italy's Export direction

4.1 Methodology

The TSOs of the Italy North Region do not perform a daily capacity calculation in export direction because the export scenarios were expected to be the unlikely market direction in the past. The export capacity for each border is currently reassessed every year, and this value is used for the daily allocation.

However, export scenarios, especially on one border of Italy (transit scenario), occurring more and more frequent recently. Therefore, the TSOs of the Italy North Region crated a roadmap for the implementation of a capacity calculation process in export direction on at least on one border (transit scenario). TSOs of the Italy North Region will implement this calculation process according to the roadmap.

Name	Beginning	End
Development Export Corner for D-2 process	**Mon 07.05.18**	**Mon 03.06.19**
Draft Methodology	Mon 07.05.18	Tue 06.11.18
Test Calculation	Mon 20.08.18	Wed 28.11.18
Implementation	Thu 01.11.18	Fri 31.05.19
Experimentation	Mon 04.02.19	Fri 31.05.19

Go-Live Export	Mon 03.06.19	Mon 03.06.19