Post-fault Activation of Flexible Resources to Manage Regional Congestions Caused by a Contingency during a Planned Outage

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***Abstract*—This paper focuses on regional and local outage planning of an electricity transmission system and presents a novel outage planning approach to solve grid congestions caused by a contingency during a planned outage in significantly surplus regions. The novel approach utilizes temporary admissible transmission loading as an enabler of a post-fault activation of flexible resources and minimizes the need to restrict the active power input into the transmission grid during a planned outage while still complying with the operational security limits. The paper presents suitable redispatching methods to implement the proposed approach, discusses its advantages and risks from three perspectives and compares it with the conventional approach. The proposed approach is expected to be more beneficial for the connected parties and the society, however, it may increase the risks and costs of a TSO compared with the conventional approach.**

***Index Terms* — congestion management, flexible resources, outage planning, remedial actions, transitory admissible overloads**

I. INTRODUCTION

More renewable, weather-dependent electricity generation is connected to the transmission and distribution grids and the amount of conventional, centralized generation is decreasing. Simultaneously, electrification is changing the consumption patterns from the past. There is an increasing need for flexibility to manage congestions and power balance in order to maintain system security. Congestions occur if the grid is not sufficient to transfer electricity from where it is generated to where it is consumed, and the operational security limits of the grid are violated. Congestion management is used by transmission system operators (TSO) to relieve or avoid grid congestions. The need for congestion management depends on the grid structure and the locations and profiles of generation and consumption.

This paper focuses on congestion management in outage planning of a transmission grid. The paper presents an approach to solve flexibility needs caused by regional or local grid congestion. In this paper, regional and local congestion refers to a grid congestion inside a bidding zone. In a certain location or region inside a bidding zone, power flows may change rapidly from the past due to an increasing amount of variable generation capacity, e.g., wind power. Regions that were in the past usually in deficit or only slightly in surplus, may become showing a high surplus with highly variable generation levels, which cause highly variable power flows. If the amount of variable generation capacity increases rapidly in a certain region, it may cause grid congestion and the violation of operational security limits in the transmission grid elements of the region especially in a case of a contingency during a planned outage of a transmission grid element.

TSOs typically operate the grid according to the N−1 criterion, which is defined by [1]. To ensure the N−1 compliance during a planned outage in a generation surplus region, a TSO may need to restrict the active power input into the transmission grid in advance, prior to the start of the planned outage. The restriction may lead to the curtailment of generation during a planned outage. The aim of this paper is to minimize the need to restrict the active power input into the transmission grid in advance for the duration of a planned outage in a surplus region. As a solution, a novel outage planning approach is presented to minimize the need for restrictions while still ensuring the N−1 compliance. The proposed approach utilizes the temporary admissible loadings of transmission lines as an enabler of a post-fault activation of flexible resources. In addition, the paper discusses market- and cost-based redispatching methods to apply the proposed approach.

The paper is organized as follows: Section II introduces power flow management, the legislative background in the context of European Union, and previous studies. Section III describes the conventional and the proposed novel approach of outage planning. Section IV presents suitable market- and cost-based redispatching methods to implement the proposed approach. Section V explains the advantages and risks of the approach from three perspectives and discusses practical challenges and future research aspects. Section VI summarizes conclusions.

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II. POWER FLOW MANAGEMENT

A. European legislation

As stated by [1], “in the N−1-situation, in the normal state each TSO shall maintain power flows within the transitory admissible overloads, having prepared remedial actions to be applied and executed within the time frame allowed for transitory admissible overloads”. The remedial actions refer to any measures applied by a TSO or several TSOs manually or automatically to maintain operational security [2]. The transitory admissible overload is defined by [1] as “temporary overloads of transmission system elements which are allowed for a limited period, and which do not cause physical damage to the transmission system elements as long as the defined duration and thresholds are respected”. Ref. [3], which has been later replaced by [1], uses terms temporary admissible transmission loading (TATL) and permanent admissible transmission loading (PATL). TATL refers to the transitory admissible overload, and PATL refers to the loading that can be accepted for an unlimited duration without any risk for the material [3]. The TATL or transitory admissible overload can be defined in multiple ways, e.g., as a fixed percentage of the permanent admissible loading for a given time such as 15 min. The percentage is specific for each transmission line e.g., usually around 110−130 % of the permanent loading of an overhead line is accepted for 15 min. The loading capability of a transmission line or a power transformer is variable and if dynamic rating is utilizable, dynamic values of admissible loadings can be used. The benefits of dynamic rating are studied e.g., in [4][5]. Fig. 2 of Appendix illustrates the principle of TATL and PATL.

B. Remedial actions

Remedial actions are used to maintain operational security and to fulfill the N−1 criterion [6]. In a case of an N−1 situation is caused by a disturbance, TSO shall activate remedial action to ensure that the system is restored to normal state as soon as possible and that this N−1 situation becomes the new N situation [1]. TSO is not required to comply with N−1 criterion if there are only local consequences unless otherwise determined by Member State [1]. Preventive remedial actions are implemented before an occurrence of a contingency (pre-fault) [6]. Curative (corrective) remedial actions are implemented after an occurrence of a contingency (post-fault) [6]. Both preventive and curative actions are prepared in the operational planning phase [6]. In the novel outage planning approach presented later in Section III, the temporary admissible transmission loadings are utilized as an enabler of curative remedial actions. In the context of this paper, curative action refers to the post-fault activation of flexible resources on request of a TSO due to a contingency. Such action is also referred to as conditional reprofiling (CRP, defined in [7]).

C. Congestion management methods

As discussed, e.g., by [8][9], congestion management methods can be divided under two categories: technical methods and non-technical methods. The technical methods include measures that are at the disposal of a TSO such as grid topology modifications, system protection schemes, installment of transformer taps and operations of compensation devices. The non-technical methods can be further divided to non-market-based (e.g., restrictions using pro-rata principle, cost-based redispatching), and market-based (e.g., market-based redispatching, countertrading, auctioning, nodal and zonal pricing). Redispatching is defined by EU regulation 2019/943 [10] as “a measure, including curtailment, that is activated by one or more TSOs or DSOs by altering the generation, load pattern, or both, in order to change physical flows in the electricity system and relieve a physical congestion or otherwise ensure system security”. Market-based and technical congestion management mechanisms in outage planning are presented in [11]. This paper (Section IV) focuses on the market- and cost-based redispatching methods relevant to grid congestions inside a bidding zone. Grid congestions and planned outages between bidding zones are not in the focus of the paper.

D. Previous studies on the utilization of temporary admissible loadings

The temporary admissible loadings as an enabler of curative congestion management have been recently studied in [12]-[14]. In [12], an approach to determine efficient preventive and curative congestion management methods by exploiting the thermal reserve of overhead transmission lines is discussed with a simulation study of future German transmission grid. In [13], the simulation study shows the theoretical potential of curative actions to reduce the need for preventive congestion management. In [14], a corrective congestion management concept for transmission grids involving fast-responding flexible units and storage systems is introduced. The method would allow higher loading levels during undisturbed operation and a reduction of preventive congestion management costs, however, the method is not yet used in practice [14]. The idea to utilize transitory (temporary) admissible loadings as an enabler of curative actions has been also presented by Elia (TSO in Belgium) in its rules for congestion management [15]-[16]. Elia has also stated that preventive actions are used if conditions for curative actions are not met, and this is generally the case with congestion bids [15]. The transitory admissible loadings as an enabler of curative actions have been used as a case-by-case solution rather than as a general, widely used application including systematic use of flexible resources by a TSO. The practical issues related to the use of the approach include increasing complexity of system operation [12], controllability and response time requirements of flexible resources [13] and need for TSO-DSO coordination [14].

III. APPROACHES OF OUTAGE PLANNING IN SURPLUS REGIONS

Planned outages are scheduled by a TSO in advance. Outage planning processes of TSOs also include outage coordination as defined in [1]. Scheduling is used as a starting point in outage planning to find a period that has minimum impact on system security and on the connected parties. Seasonal level scheduling can be used to reduce the risk of congestion. However, as the amount of weather-dependent, variable generation increases in the grid, scheduling of planned outages in advance to a period where no congestion occurs in an N−1 condition is extremely challenging [17]. This is especially the case with planned outages that have a longer duration (from several days to several weeks) and are in significantly surplus regions (high weather-dependent generation, low consumption). The presented conventional and novel approaches of outage planning are applicable in significantly surplus regions, and when scheduling and technical methods are not sufficient to ensure the N−1 compliance. Examples of such regional and local surplus scenarios are presented in [17].

A. Conventional approach of outage planning

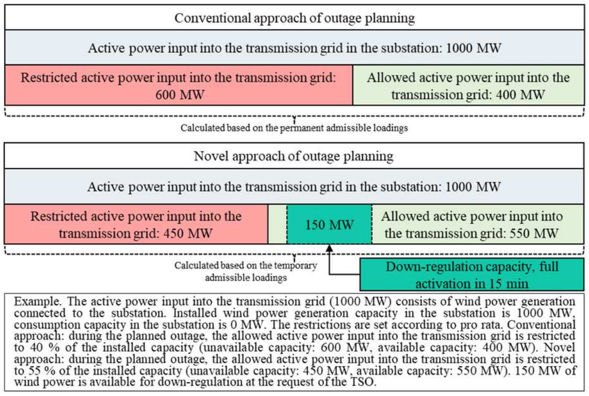
In this approach, preventive actions are used by a TSO before the day ahead market closure to ensure the N−1 compliance during a planned outage in a surplus region. The active power input into the transmission grid is restricted in the relevant grid locations according to the permanent admissible loadings. The temporary admissible loadings are not utilized. Such approach is referred to as conventional in this paper (Fig. 1). The restrictions of connected parties are set according to the grid service terms and conditions of a TSO, which usually addresses the need to restrict or interrupt the grid service due to maintenance, modification, or investment (without financial compensation). In surplus cases, the connected party refers to a party that inputs electricity into the transmission grid, i.e., generation and storages connected to TSO's grid or a DSO having distributed generation or storages connected to its grid. The amount of the restriction can be adjusted by the TSO closer to the planned outage as the power flow forecasts of the region become more accurate. The restrictions are publicly informed by a TSO (urgent market message, UMM), e.g., in the Nordic countries via NUCS system. The restrictions, i.e., the maximum allowed active power input into the transmission grid, of the connected parties are set the latest before the gate closure of the day ahead spot market. The impacted generation and storage facilities can take the restrictions into account in the day ahead trading and thus, these restrictions do not cause any imbalances. The restriction procedure of connected parties shall be done in transparent and non-discriminatory manner by a TSO, e.g., using pro rata when all impacted generation facilities are renewable. In the pro rata principle, the restriction is shared equally across the connected parties in the relevant locations. The restriction of active power input into the transmission grid may lead to the curtailment of generation during a planned outage. The amount of curtailed generation is dependent on how much the facility would have generated without the restriction.

B. Novel approach of outage planning

This approach relies on the use of preventive actions before the day ahead market closure to ensure the N−1 compliance during a planned outage, but it also utilizes curative actions. As in the conventional approach, the active power input into the grid is restricted in the relevant locations in advance in non-discriminatory manner. As a difference from the conventional approach, the operational security limits are calculated and the restrictions are set according to the temporary admissible loadings. The temporary admissible loadings are utilized as an enabler of a post-fault activation of flexible resources. The approach minimizes restrictions and thus a higher active power input into the transmission grid is allowed during a planned outage (Fig. 1). Such approach is referred to as novel in this paper.

The availability of flexible resources in specific locations is a prerequisite for the use of this approach. The flexible resources are activated on request of the TSO. In a case that an N−1 condition during a planned outage causes a need for activation of flexible resources, the full activation of the flexible resources must be done within the required time frame of the temporary admissible loadings (15 min in this approach). Fig. 1 presents an example of the novel approach. Fig. 3 of Appendix illustrates the impact of a post-fault activation of flexible resources on the power flow of a transmission line. The down-regulation could be provided either by generation or consumption facilities or storages in suitable locations. In the regional surplus cases, the restrictions of active power input into the transmission grid concern generation and storage facilities and thus those resources are likely having the highest incentive to provide down-regulation since that will allow higher active power input into the transmission grid during a planned outage. The needed down-regulation capacity can be procured by a TSO well in advance, e.g., weeks or months ahead, from relevant locations to guarantee its availability during a planned outage (presented later in Section IV).

In the N−1 condition during a planned outage, the maximum number of activated hours of down-regulation is 36, i.e., from the gate closure of the day ahead spot market to the end of the operational day. However, the number of activated hours is likely less than 36 since it is dependent on: 1) does the contingency cause a need for down-regulation and for how many hours, 2) what is the duration of the contingency (permanent fault), and 3) what is the time of day when the contingency occurs (more details in Fig. 4 of Appendix). If the contingency and planned outage continue in the following days, preventive actions before the gate closure of the day ahead market are utilized by a TSO, i.e., the restrictions of active power input into the transmission grid are increased by a TSO considering the new operational security limits. The process of the novel outage planning approach is presented in Fig. 4 of Appendix.



Example. The active power input into the transmission grid (1000 MW) consists of wind power generation connected to the substation. Installed wind power generation capacity in the substation is 1000 MW, consumption capacity in the substation is 0 MW. The restrictions are set according to pro rata. Conventional approach: during the planned outage, the allowed active power input into the transmission grid is restricted to 40 % of the installed capacity (unavailable capacity: 600 MW, available capacity: 400 MW). Novel approach: during the planned outage, the allowed active power input into the transmission grid is restricted to 55 % of the installed capacity (unavailable capacity: 450 MW, available capacity: 550 MW). 150 MW of wind power is available for down-regulation at the request of the TSO.

Figure 1. Example of the conventional and the novel approach of outage planning in a significantly surplus region.

In a case that a TSO is trying to procure regulation capacity from the resources in relevant locations in advance (e.g., weeks to a few months prior to a planned outage) to guarantee its availability during a planned outage, but does not receive sufficient bids, i.e., bids are not available or reasonable priced, a TSO can opt to use the conventional approach and set the restrictions according to the permanent admissible loadings. In specific local planned outage cases, risk-taking, i.e., the N−1 compliance is not completely guaranteed by restrictions nor flexible resources, could be considered by a TSO if the consequences are local and there is no risk of a system level impact.

IV. REDISPATCHING METHODS SUITABLE TO IMPLEMENT THE NOVEL OUTAGE PLANNING APPROACH

There is no standardized product for redispatching in Europe, and various methods are applied based on the specific redispatching needs of a country. Redispatching can be done in a market- or cost-based way and participation of resources can be voluntary or mandatory or a combination of both. The EU regulation 2019/943 [10] highlights that redispatching shall be done in a market-based way. However, non-market based redispatching can also be applied if certain conditions described in [10] are met e.g., all market-based resources have been used or there is no effective competition. All the presented redispatching methods in this section are capable of implementing the novel outage planning approach upon condition that the flexible resources can be activated post-fault within max. 15 min. It is also essential to know the locational information of a flexible resource (connection point to the transmission grid). The flexible resources are selected for redispatching based on the price (cost), and the location of the resource (the impact of activation on congestion). To maintain the balance in the control area, a corresponding amount of regulation is activated in the opposite direction outside the congested location by the TSO. An overview and a comparison of the redispatching methods presented in this section is provided in Table I and Table II of Appendix.

A. Market-based methods

1) mFRR special regulation: Manual Frequency Restoration Reserve (mFRR) refers to balancing energy and capacity markets used in several European countries [18]. mFRR special regulation refers to a regulation that is ordered for other purposes than balancing [19], such as redispaching. The balancing energy bids used for redispatching shall not set the balancing energy price [10]. mFRR special regulation is remunerated based on the pay as bid principle, e.g., in Finland pay as bid, but the price is at least the same as the up-regulation price of the hour / does not exceed the down-regulation price of the hour [19]. The mFRR energy bids should be fully activated in 15 min (currently in the Nordic countries) [19]-[23], and after the European standard mFRR product (MARI), the bids are fully activated in 12.5 min [24]. The mFRR special regulation is used for congestion management e.g., in the Nordic countries [19]-[23] and in Belgium [15]. In Denmark, locational information (“geo-tags”, connection point to the transmission grid) to mFRR energy bids is to be required to avoid and solve local congestions [22]-[23], and a requirement to add geo-tags to aFRR (Automatic Frequency Restoration Reserve) energy bids is in process [25]. The availability of an mFRR energy bid is dependent on the balancing service provider (BSP) if bidding is voluntary, and there is no guarantee that energy bids in relevant locations are available during a planned outage unless the TSO has used locational capacity procurement prior to the planned outage to guarantee availability. It is also possible to obligate facilities via national grid codes to put at the disposal of a TSO the active power that remains available on the facilities that fulfill the mFRR requirements and have an installed capacity larger than a predefined value, such procedure is used for generation and storages in Belgium by Elia [26]-[27].

2) Locational redispatching capacity procurement (a tender process, energy bids to mFRR): A TSO can procure regulation capacity from relevant locations in advance, e.g., weeks or months prior to the planned outage, for the duration of the planned outage to guarantee the availability of flexibility. The procurement is organized as a local redispatching capacity auction, i.e., a one-off auction for the duration of a planned outage. The selected flexible resources are obliged to offer mFRR energy bids during the planned outage as agreed in the terms and conditions of the capacity procurement. The energy bids are activated for congestion management as mFRR special regulations. The mFRR energy bids can be also activated for balancing (pay as cleared). The price of the capacity bid and mFRR energy bid is determined by the BSP, which may cause a risk of strategic bidding and locational market power.

3) Locational redispatching capacity procurement (a tender process of bilateral contracts): A TSO organizes a tender process of bilateral contracts to guarantee the availability of down or up regulation during a planned outage in relevant grid locations. This option allows the participation of flexible resources that do not fulfill the requirements of a standardized balancing energy product (mFRR) but are still capable of providing regulation within the required time frame. The tender process is competitive if there are several participants. The requirements of the activation are agreed in the bilateral contract. Bilateral contracts can be also used to implement preventive actions. Bilateral contracts are used in congestion management e.g., in the Netherlands by Tennet [28].

4) Locational redispatching capacity procurement (flexible connections): This option differs from the other capacity procurement methods as the obligation to offer regulation is already set in the connection agreement between the TSO and the connected party. The resources under market-based flexible connection agreements are activated on-demand, e.g. utilizing mFRR as presented in [29]. The flexible connections are applicable in outage planning if the resources under these agreements are in relevant locations.

5) Locational weighting on balancing capacity market: The locational capacity procurement is done as a part of an existing mFRR capacity market. The capacity bids are selected based on the price and location. The selected BSPs are obliged to bid to the mFRR energy market, and the price of the energy bid is set by the BSP. mFRR special regulation is used if the energy bids are activated for redispatching. As a difference from the other capacity procurement methods described by the paper, it might not be possible to procure the capacity in advance for the whole duration of a planned outage (unless the duration of a planned outage is short). Balancing capacity markets are organized e.g., as a daily (day ahead) procurement [19]. If participation to balancing capacity and energy markets is voluntary, there is no guarantee that bids in relevant locations will be available for the whole duration of a planned outage.

6) Redispatching market: In this paper, a redispatching market refers to a product that is specifically used for congestion management. Bidding to the redispatching market can be voluntary or mandatory or a combination of both. The same flexible resources can participate in balancing markets and redispatching markets, but if the bid is selected for either one, it is not available on the other market for the same ISP (imbalance settlement period). In a case of a contingency during a planned outage occurs and causes a need to activate flexible resources, redispatching bids would be activated by a TSO from relevant locations within the time requirements (max. 15 min in the novel approach of this paper) and at the lowest possible prices. A redispatching market is used e.g., in the Netherlands by a product "Reserve Power Other Purposes" (pay as bid) [30]. In this product, participation is a combination of mandatory (consumption or generation capacity > 60 MW) and voluntary (< 60 MW) [30]-[31]. Currently, the preparation period is 3 ISPs or more [30], meaning that the bids are likely activated preventively during the operational day, and the full activation time (45 min or more) as such is too long for the approach presented by this paper.

B. Cost-based method

Cost-based redispatching refers to mandatory participation with the reimbursement of occurred costs. Cost-based redispatching can be used to avoid the risk of strategic bidding and locational market power. However, the integration of consumption into cost-based redispatching is more difficult than in the market-based redispatching due to the difficulty of defining a cost-based compensation of a redispatched load (individuality) [32]. Cost-based redispatching is utilizable in the novel outage planning approach if the resources can be fully activated in 15 min (currently, might not be the case). Cost-based and mandatory redispatching is used in Germany [33]-[34] and it is generally done as a preventive action (i.e., not in real time). As another example, Belgium has appealed from the use of a market-based method and used a cost-based redispatching method for the activation of flexibility offered in the day ahead procedure time frame [15] (used as a preventive action, not in real time).

V. DISCUSSION

The proposed novel outage planning approach allows higher active power input into the transmission grid during a planned outage compared with the conventional approach. The financial benefits of the lower restrictions of active power input into the transmission grid are dependent on how much more the facilities would be able to generate during the planned outage compared with the conventional approach. The proposed approach provides incentives especially for generation and storages to offer down-regulation during a planned outage, since those are impacted by the level of restrictions in surplus cases. Moreover, the flexible resources providing redispatching are remunerated while in the conventional approach flexible resources are not utilized. The restrictions of active power input into the transmission grid impact renewable generation (assuming there is no non-renewable generation in relevant location). Higher amount of allowed active power input into the transmission grid during a planned outage will also likely impact the electricity spot prices during the planned outage (lower prices). From the point of view of the connected parties and the society, the novel approach is expected to be more beneficial in comparison with the conventional approach. Quantitative analysis of the financial benefits of the proposed approach is to be done as a future work to show its cost-efficiency in practice.

The novel approach may increase the risks and costs of a TSO compared with the conventional approach. In the novel approach, a TSO aims to minimize the restrictions during a planned outage by utilizing flexible resources. There are risks (price, availability) related to market-based bids but, in a case of a contingency, also to the activation of the corresponding amount of regulation in the opposite direction to maintain balance in the control area. On the other hand, a permanent fault during a planned outage is extremely unlikely and thus it is also unlikely that a TSO would need to activate flexible resources due to a permanent fault during a planned outage. The operational costs of the approach may cause a negative impact on TSO's profit unless relevant economic regulation is amended to incentivize the utilization of operational flexibility [35].

Section IV presented various redispatching methods capable to implement the proposed novel outage planning approach. The advantages, weaknesses and risks of each method are presented in Table II of the Appendix. The selection of the redispatching method to implement the novel approach is dependent on how congestion management and redispatching are overall done in a country. The balancing energy market (mFRR / MARI) fulfills the 15 min full activation time requirement and if mFRR special regulation is already used for redispatching, locational capacity procurement with energy bids to the mFRR energy market could be a suitable option to implement the novel approach if there is enough liquidity. The scarcity of flexible resources in relevant locations is a challenge as it causes lack of competition and risk of strategic bidding. As an example, in Finland, the participation of wind power to mFRR is currently low [36] causing a barrier to use the novel outage planning approach in surplus regions. In addition, the requirement of locational information of a bid means additional work for the flexibility provider if such information has not been required in the past. The temporary admissible transmission loadings will not be technically utilizable in all cases if the cause of the violation of the operational security limits is not thermal overloading.

This paper focused on outage planning in significantly surplus regions inside a bidding zone. The proposed approach is driven by the rapid growth of renewable, weather-dependent generation. A similar approach could be applicable to planned outages in deficit regions where active power output from the transmission grid needs to be temporarily restricted to comply with the operational security limits. In such cases, locational up-regulation could be utilized by a TSO to reduce the restrictions. Moreover, the lack of transmission capacity is an increasing issue. The proposed approach to utilize temporary admissible loadings as an enabler of post-fault activation of flexible resources is an applicable method for congestion management in general, not only for the outage planning use case that was focused on this paper. However, a redispatching method capable to activate the flexible resources in a certain grid location within the required time frame is a prerequisite for the use of the proposed approach in practice.

VI. CONCLUSIONS

The paper presented a novel outage planning approach utilizing temporary admissible loadings as an enabler of a post-fault activation of flexible resources and compared it with the conventional approach. The novel approach minimizes the need for restrictions during planned outages while ensuring the compliance with operational security limits. The proposed approach is expected to be more beneficial for the connected parties and the society, however, it may increase the risks and costs of a TSO compared with the conventional approach.

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APPENDIX

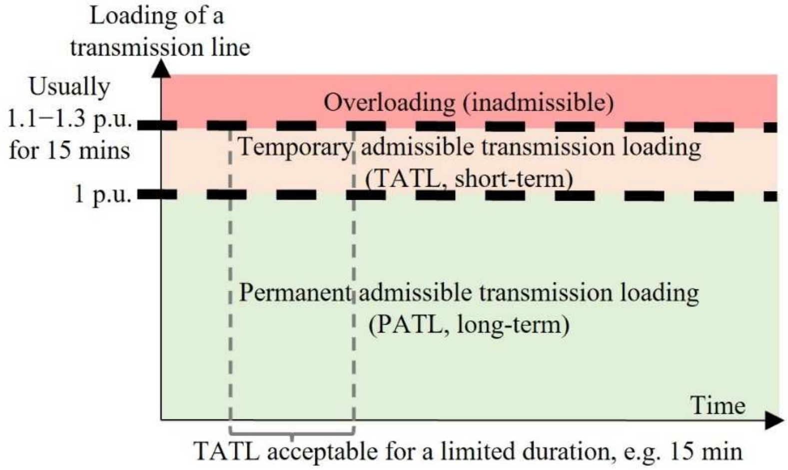

Figure 2. Principle of temporary and permanent admissible transmission loadings.

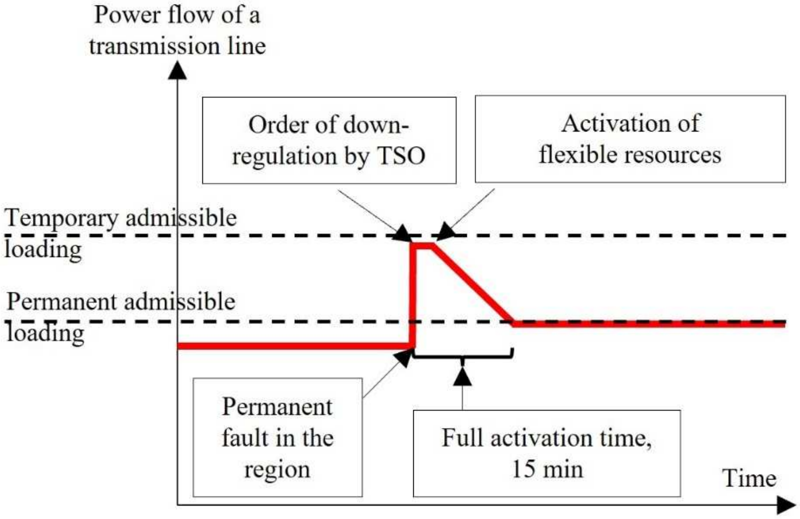

Figure 3. Illustration of impact of a post-fault activation of flexible resources to the power flow of an overhead transmission line in an N−1 condition during a planned outage.

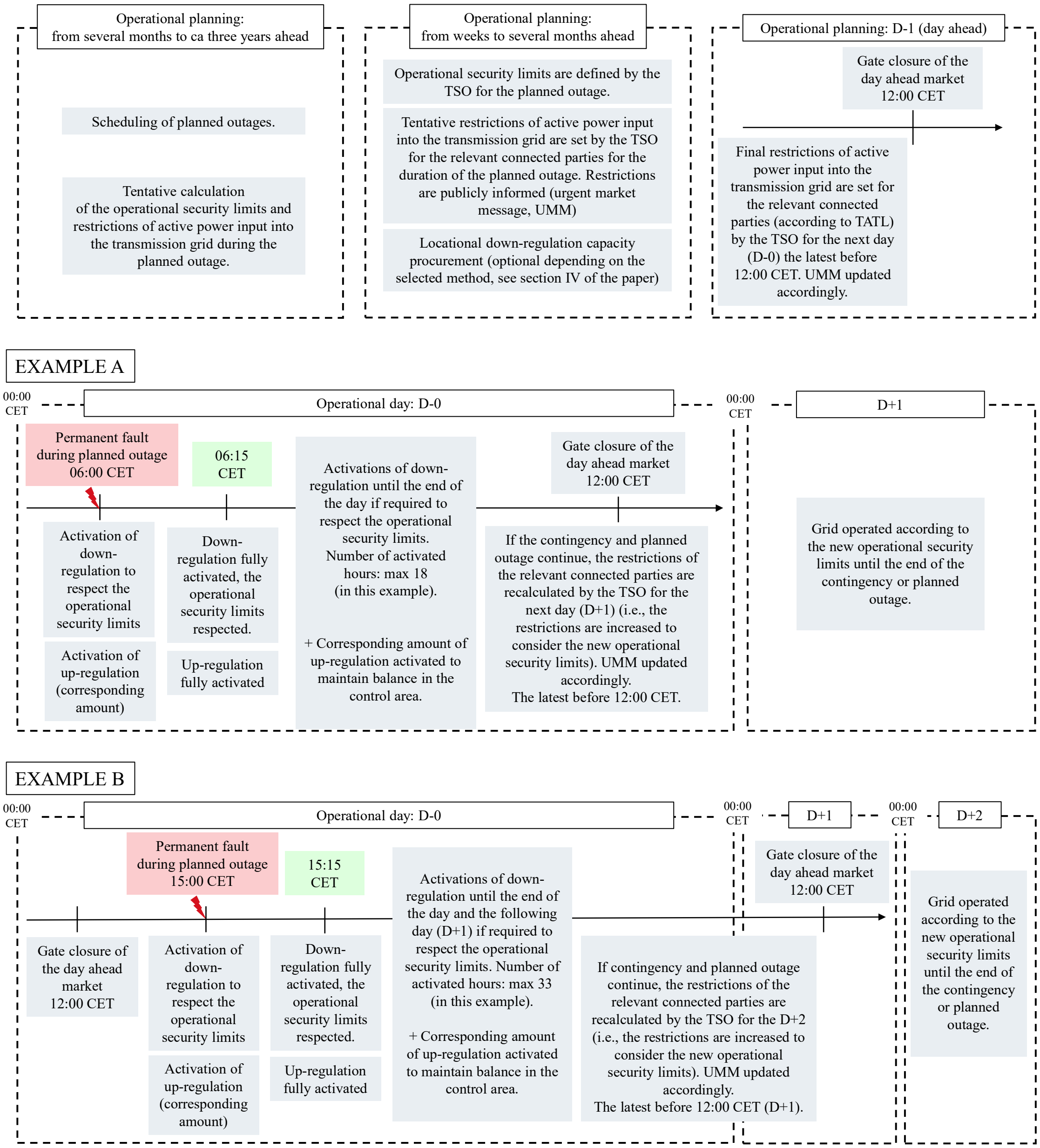

Figure 4. The process of the novel outage planning approach presented in Section III. Two examples of permanent faults are presented to illustrate the impact of the time of the occurrence of the permanent fault to the process in the D-0, the D+1 and the D+2 time frames.

TABLE I. OVERVIEW OF THE REDISPATCHING METHODS PRESENTED IN SECTION IV.

	Redispatching methods						
	mFRR special regulation	***Locational capacity procurement (energy bids to mFRR)***	***Locational capacity procurement (bilateral contracts)***	***Locational capacity procurement (flexible connections)***	***Locational weighting on mFRR capacity market***	***Redispatching market***	***Cost-based redispatching***
Market-based	YES	YES	YES	YES	YES	YES	NO
Capacity procurement (to guarantee availability)	NO	YES (one-off)	YES (one-off)	YES (connection agreement)	YES (e.g., daily)	YES / NO	NO
Capacity payment	NO	YES	YES / NO (as agreed)	NO	YES	YES / NO	YES / NO
Energy payment (redispatching)	Pay as bid	Pay as bid	As agreed	Pay as bid	Pay as bid	Pay as bid	Cost-based
The same bid can be also used as a balancing energy bid	YES	YES	NO	YES	YES	NO	NO
Full activation time (FAT) (min)	15 / 12.5 in MARI	15 / 12.5 in MARI	As agreed	15 / 12.5 in MARI	15 / 12.5 in MARI	As defined in the rules.	As defined in the rules.
Participation: Voluntary / Mandatory	Voluntary bids (depends on the BSP). / Mandatory if national grid codes require.	Mandatory energy bids during the contracted period.	Mandatory energy bids during the contracted period.	Mandatory, as agreed in the connection agreement.	Mandatory energy bids during the contracted period.	Mandatory if national grid codes require. / Voluntary.	Mandatory, as required by the national grid codes.
Link between balancing and redispatching	Balancing and redispatching via mFRR energy bids.	Balancing and redispatching via mFRR energy bids. Separate redispatching and balancing capacity procurement.	Balancing markets and redispatching markets separated.	Balancing and redispatching via mFRR energy bids. Separate redispatching and balancing capacity procurement.	Balancing and redispatching via mFRR energy bids. Common redispatching and balancing capacity procurement.	Balancing markets and redispatching markets separated.	Balancing markets and redispatching separated.

TABLE II. COMPARISON OF THE REDISPATCHING METHODS TO IMPLEMENT THE PROPOSED NOVEL OUTAGE PLANNING APPROACH. THE TABLE IS FILLED FROM THE POINT OF VIEW OF OUTAGE PLANNING USE CASE.

	Redispatching methods						
	mFRR special regulation	***Locational capacity procurement (link to mFRR)***	***Locational capacity procurement (bilateral contracts)***	***Locational capacity procurement (flexible connections)***	***Locational weighting on mFRR capacity market***	***Redispatching market***	***Cost-based redispatching***
Advantages (TSO)	Utilization of an existing mFRR energy product. Enables technology neutral participation (generation, consumption, storages). No capacity payment.	Utilization of an existing mFRR energy product. Availability of suitable resources guaranteed for the duration of the planned outage. Enables technology neutral participation.	Availability of suitable resources guaranteed for the duration of the planned outage. Enables technology neutral participation. Enables the participation of resources that do not fulfill the mFRR requirements / do not participate in mFRR.	Availability of the resource guaranteed by connection agreement. No capacity payment. Enables technology neutral participation. Can be linked to mFRR.	Utilization of existing mFRR capacity and energy products. Enables technology neutral participation.	Availability of suitable resources can be guaranteed for the duration of the planned outage. Enables technology neutral participation. Enables the participation of resources that do not fulfil the mFRR requirements / do not participate in mFRR.	No risk of the prices of energy and capacity bids, no risk of locational market power. No risk of availability due to mandatory participation.
Weaknessess (TSO)	Does not allow the participation of resources that do not fulfill the mFRR product requirements / do not participate in mFRR.	Does not allow the participation of resources that do not fulfill the mFRR product requirements / do not participate in mFRR. New capacity procurement procedure.	New tender procedure: rules, IT systems, data exchanges etc.	Need to be agreed when the resource is connecting to the transmission grid.	Does not allow the participation of resources that do not fulfill the mFRR product requirements / do not participate in mFRR.	New product: new processes, market rules, IT systems, data exchanges etc.	Requires new processes, rules, IT systems, data exchanges etc.
Risks (TSO)	The price of mFRR energy bids, locational market power. Availability of suitable bids not guaranteed for the duration of a planned outage (if voluntary participation).	The price of capacity bids and mFRR energy bids, locational market power.	The price of bilateral contracts, locational market power.	Flexible connections may not be in suitable locations or the capacity under these agreements fulfills the need only partially. The price of the energy bid.	The price of mFRR capacity & energy bids, locational market power. Locational weighting impacts balancing capacity procurement. Availability of suitable bids not guaranteed in advance for the whole duration of the planned outage, possibly results in additional work / risk.	Prices of bids, locational market power. Availability of suitable bids not guaranteed for the duration of a planned outage if voluntary participation and no capacity procurement.	Difficult to integrate consumption resources into cost-based redispatching. Redispatching may be provided only by generation and storage facilities (potentially impacts costs).
Advantages (flexibility provider)	New business opportunity. Participation in redispatching and balancing via the same mFRR energy bid.	New business opportunity. Capacity payment. Participation in redispatching and balancing via the same mFRR energy bid.	New business opportunity. (Capacity payment.)	Allows earlier connection of a resource to the transmission grid. New business opportunity.	New business opportunity. Capacity payment. Participation in redispatching and balancing via the same mFRR energy and capacity bids.	New business opportunity. (Capacity payment.)	Occurred costs remunerated.
Weaknesses / Risks (flexibility provider)	No capacity payment. Requires fulfillment of mFRR requirements.	Participation requires fulfillment of mFRR requirements.	Participation in redispatching and balancing via separate bids requires additional work. (No capacity payment.)	Requires fulfillment of mFRR requirements (if activation linked to mFRR). No capacity payment.	Participation requires fulfillment of mFRR requirements.	Participation in redispatching and balancing via separate products requires additional work. (No capacity payment.)	No new business opportunities. Additional work to comply with the rules of redispatching.