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# Report on the blackout in Italy on 28 September 2003

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## Summary

**Sequence of events:** The north-south transit lines through Switzerland were very heavily loaded just before the blackout occurred early in the morning of 28 September 2003 in Italy and in certain southern regions of Switzerland. However, as was frequently the case during the nights prior to the blackout, the transmission lines from France to Italy were not operating at full load at the time the incident occurred. At 3.01 a.m., one of the main north-south transit lines – the Lukmanier transmission line – shut down following a flash-over between a conductor cable and a tree. This resulted in a redistribution of the electricity in accordance with the laws of physics, and a subsequent overload (110%) of another north-south transit line, namely the San Bernardino transmission line.

After ATEL had made several attempts to restore the Lukmanier line, ETRANS (the responsible Swiss network operator) contacted the Italian network operator GRTN by telephone at 3.11 a.m. to request it to adjust the existing unscheduled import discrepancy of approximately 300 MW in order to lower the overload on the San Bernardino line to around 100%. The action taken by ETRANS was based on an internal checklist. GRTN only reached the requested adjustment to the import volume at 3.21 a.m., i.e. after 10 minutes.

The next step to be taken by ETRANS would have been to reduce still existing heavy transit flows through Switzerland by issuing instructions to GRTN and the French network operator, RTE. GRTN should have switched off pumps at pumped storage power stations. RTE should have taken measures to reorganise production in French territory and in other zones with major French export capacities. The objective here would have been to reduce transit flows through Switzerland to such an extent that it would have been possible to restore the Lukmanier transmission line. But this was prevented by an line to ground fault at 3.25 a.m. on the San Bernardino line, which subsequently led to its shut-down as well. There then followed a series of failures of other transmission lines in the border region, possibly caused by inadequate measures on the part of GRTN to preserve stability. The resulting shutdown of power plants in Italy caused the simultaneous failure of voltage and frequency, and this in turn gave rise to a blackout throughout Italy at 3.27 a.m.

**Analysis:** Over the past few years, Italy's electricity imports have grown sharply due to the significant discrepancies in electricity production costs between Italy and the rest of Europe. Over the past few years, the fact that Switzerland has not been directly involved in developments within the European electricity market has meant that the constantly increasing volume of imports into Italy has been distributed among France and Switzerland as the two main exporting countries without any influence on the part of the Swiss authorities, so that loads on cross-border transmission lines often deviate from allocated trading quotas, and ever greater – and unplanned – volumes have to be absorbed by the Swiss transmission lines. Over the past years, French electricity traders have been allocated export volumes that exceed France's maximum permissible physical cross-border transmission capacity to Italy. By contrast, Swiss electricity traders have been allocated export volumes that are below Switzerland's available physical capacity for export to Italy. Commercial allocations of this nature give rise to deviating physical loads on transit and cross-border transmission lines from Switzerland to Italy (loading above agreed levels) and from France to Italy (loadings below agreed levels). Reference load flows show that it is possible to significantly reduce such deviations by reorganising injections from power plants in Europe.

Networks within the UCTE (Union for the Co-ordination of Transmission of Electricity) are operated in such a manner as to ensure secure supply even after the failure of any component (= N-1 security). However, if a major transmission line is shut down, and shortly afterwards a second major transmission line is unexpectedly shut down automatically – and this is precisely what happened following the line to ground fault on the San Bernardino line – then it is no longer possible to secure uninterrupted supply. For this reason, the corrective measures to be taken interactively by the network operators in Switzerland, France and Italy should have been implemented more rapidly and co-ordinated more efficiently. The questions as to why other international transmission lines to Italy – i.e. those from France, Austria and Slovenia – were shut down after 3.25 a.m., what led to the blackout in Italy, and whether GRTN's precautionary isolation measures were sufficient, all need to be examined in greater detail.

**It would appear that the main causes of the blackout in Italy were a line to ground fault on the Lukmanier line, the inability to restore this line, a phone call between ETRANS and GRTN that did not take adequate account of the severity of the situation, possible instabilities in the GRTN network, and perhaps insufficient distances between conductor cables and trees. But these are merely factors that triggered the blackout. The underlying causes of the incident that occurred on 28 September 2003 are the unresolved conflicts between the trading interests of the involved countries and operators and the technical requirements of the existing transnational electricity system. Present-day standards and legal instruments are lagging well behind economic realities.**

### **Recommendations**

- For Switzerland, national and pan-European supply security and a sustainable policy for the electricity sector are of the highest priority, both today and in the future.
- Switzerland regards the binding and sovereign regulation of international electricity trading as foreseen in the EU electricity ordinance (1228/2003) to be of the utmost urgency.
- Switzerland is willing to actively assist in the formulation and implementation of this EU ordinance on the newly formed committee of European electricity and gas market regulators.
- In the procedures for allocating transmission capacities to Italy for 2004 and after, Switzerland wishes to have a right of co-determination together with the regulators of France and Italy.
- The Swiss Federal Office of Energy intends to intensify its ongoing observation of trends on the Swiss and European electricity markets, and to make it more systematic.
- Within the scope of the federal government's crisis organisation, the suitability of decision-making procedures and the measures prepared for handling power failures are to be closely examined.
- The Swiss Federal Office of Energy recommends proprietors of Swiss transmission lines to create a Swiss network operator as an independent operator of the transmission network as soon as possible and – without waiting for the introduction of legal provisions governing the electricity industry – on a voluntary basis.
- Switzerland urgently needs a comprehensive federal law governing the electricity industry. A consultation process concerning the regulation of the electricity industry should take place by the second half of 2004 at the latest – if necessary in the form of a conference.
- Switzerland urgently needs a strong regulator who is able to regulate and control the market as an equal partner together with regulators of neighbouring countries and the EU Commission. This institution is a high priority in view of the urgent need for regulation in the areas of crisis prevention and handling.
- DETEC and the SFOE are examining the possibility of introducing an urgent decree aimed at establishing the necessary institutions and competencies for guaranteeing a secure electricity supply in Switzerland and enabling Switzerland to have a say on the European electricity market. The associated experts commission is to issue a statement of position on 16 December 2003 concerning the suitability of this procedure and the various elements to be incorporated into the decree (regulator, Swiss network operator, degree of market liberalisation). The decree would enable a regulated transition until the introduction of a comprehensive electricity industry ordinance.

# Introduction

The aim of this report, which was prepared on the basis of a mandate of the Federal Department of Environment, Transport, Energy and Communications (hereinafter referred to as DETEC) dated 3 October 2003, is to deal with the following issues:

- Development of European electricity trading, and applicable regulations for this activity (Section 1).
- Assessment of the sequence of events on 28 September 2003 and the behaviour of the involved electricity companies. One of the bases for discussion is the report by the UCTE<sup>1</sup> dated 27 October 2003, "Interim Report of the Investigation Committee on the 28 September 2003 Blackout in Italy", which looks into four potential causes of the blackout (Section 2).
- Duties of the Swiss authorities (in particular, the Federal Office for National Economic Supply and the Federal Inspectorate for Heavy Current Installations), and the extent of their room for manoeuvre. The supervisory activity of the Inspectorate is assessed in an independent expertise by the law firm of Binder, Baden (Section 3).
- Conclusions and recommendations arising from the blackout of 28 September 2003. These are addressed to the involved electricity companies and the political authorities responsible for electricity issues in Switzerland and abroad (Section 4).

The SFOE questioned the Swiss co-ordination office, ETRANS<sup>2</sup> and the directly involved electricity companies, and analysed the relevant documents. These tasks were carried out with the assistance of Professor H. Glavitsch, who was Director of the Institute for Electrical Energy Transmission and High-Voltage Technology at the Federal Institute of Technology, Zurich, up to the end of 1999. The SFOE's studies and subsequent conclusions were kept entirely independent of the electricity industry.

The SFOE relied on information available to it up to the middle of November, and reserves the right to revise its statements if necessary on the basis of new findings. It should be noted here that additional documentation will shortly be available, including the final report of the UCTE and a study conducted by Nordel<sup>3</sup> that was carried out at the joint request of the electricity market regulators of Italy and France, as well as the SFOE.

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<sup>1</sup> UCTE ([www.ucte.org](http://www.ucte.org)): Union for the Co-ordination of Transmission of Electricity

<sup>2</sup> ETRANS: ([www.ETRANS.ch](http://www.ETRANS.ch)) "ETRANS performs two functions: it is the independent co-ordinator for the Swiss ultra-high-voltage network, and provides services associated with the tasks of the European (UCTE) network operators. ETRANS is independent in terms of specific interests of manufacturers, distributors and trading companies. It combines its know-how, tools, infrastructure and data to provide a variety of services to Swiss and European network operators."

<sup>3</sup> Nordel ([www.nordel.org](http://www.nordel.org)) "is a body for co-operation between the transmission system operators in the Nordic countries (Denmark, Finland, Iceland, Norway and Sweden), whose primary objective is to create the conditions for, and to develop further, an efficient and harmonised Nordic electricity market."

# 1 Development of cross-border electricity trading and its regulation

## 1.1 Previously applicable regulations in the European integrated network

A co-ordinated European electricity transmission network was first formed in the 1950s, and has been undergoing expansion ever since. This network forms the backbone for a reliable and inexpensive electricity supply. The principle of co-ordinated production makes it possible to utilise the cost benefits of large thermal power plants and hydropower plants, since short-term energy can be additionally supplied by storage power plants and gas turbines to offset peak demand. In a network that integrates all power plants, only a small number need to be kept in reserve at the regional level, and security of supply is enhanced at the same time.

In the event of malfunctions at power plants or extraordinary supply situations (very cold or very hot periods, sustained periods of drought, etc.), it is also possible to transport the required reserve capacities over greater distances. However, the transmission network is only suitable to a limited extent for large-scale energy transport over long distances and extended periods of time, since local interruptions are possible at any time due to lightning, storms, avalanches and other natural occurrences over which we have no control. For this reason, network operators defined a variety of measures to be taken in order to prevent local outages from spreading to the entire network and to provide mutual assistance when such problems arise.

Co-operation within the integrated network is regulated on the basis of various principles and recommendations of the UCTE. All operators of transmission networks in 23 countries in Europe are affiliated to this organisation. All network operators involved in the incident that occurred on 28 September 2003 are members of the UCTE, and are therefore subject to its voluntary regulations.

These range from principles governing the balance between production and consumption, to adjustment of voltage and frequency, exchange and transit supplies, network security and stability, measures to prevent major interruptions, reciprocal measures for restoring power following a network failure, and exchange of information among members. In association with the blackout in Italy, for example, observation of the N-1 principle was of particular significance. This states that it must be possible to continue operating a network even after the failure of a given transmission line or an interruption in the supply of power.

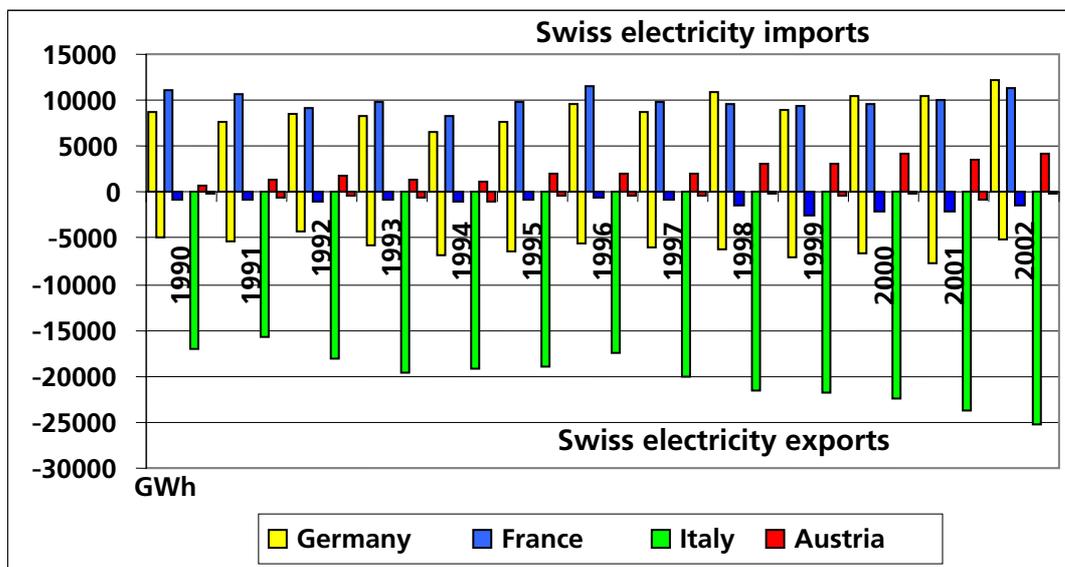
## 1.2 Development of electricity transmission to Italy via Switzerland

In view of its central geographical location, its energy production and storage capacities thanks to the utilisation of hydropower, and its dense high-capacity transmission network, Switzerland effectively functions as an electricity supply hub. The volumes of electricity imports and exports between Switzerland and Germany are practically identical, and this is an indication of the degree of complementarity that exists between production from thermal power plants in Germany and the use of hydropower in Switzerland. By contrast, Switzerland's trade with France and Austria is primarily in the form of imports.

Electricity exports to Italy have been rising constantly over the past few years. As can be seen from Fig. 1, Switzerland's electricity exports to Italy amounted to more than 25,000 GWh in 2002. This is attributable to the fact that Italy is currently only able to meet 87% of its annual domestic energy demand, and therefore relies heavily on imports. On top of this, most of its ageing power plants are

oil-fired and their operating costs are thus very high, so they are normally only used during periods of high demand. The high costs associated with domestic electricity production, combined with options for purchasing electricity via the European market at favourable prices, mean that Italy is meeting an ever-increasing proportion of its domestic demand through imports. Thus during periods of low demand on the European electricity market, as was the case during the night of 28 September 2003, Italy makes full use of the available import capacities. On 28 September 2003 (3 a.m.), the import volume was 6,651 MW, while the domestic load was 27,702 MW (3,638 MW of which was intended for pump-fed power plants, which feed water into reservoirs at higher altitudes that is subsequently used for producing electricity). This figure is equivalent to an import quota of 24%. More than half of this volume (54%) was delivered via Switzerland, while approximately one-third came from France.

Fig. 1: Switzerland's import/export balance for electrical energy: physical electricity imports and exports, 1990 to 2002



### 1.3 Electricity exports to Italy

In view of the critical bottleneck that exists in terms of transmission lines for Italy's electricity imports, the operators of the transmission networks of Italy, France and Switzerland – and more recently together with their counterparts in Austria and Slovenia – hold regular discussions at which they negotiate on the allocation of import capacities. During the winter months the total gross import capacity of Italy is 7,000 MW, while the equivalent figure for summer is 6,000 MW due to higher temperatures. After a deduction of 500 MW reserve capacity for securing a reliable supply, the net import capacities that have to be shared among the transmission lines operated by the four countries exporting electricity to Italy, are 6,500 MW in winter and 5,500 MW in summer. The network operators of all involved countries are required to allocate these net import capacities in such a way as to ensure that the security criteria (e.g. N-1) and other factors that influence the physical flow of electricity, can be duly adhered to.

Here, the Italian network operators are clearly interested in a capacity allocation procedure that focuses solely on meeting the criteria of security and stability of the system. The reason for this is that load flow forecasts – which serve as the reference for the determination of commercial export trade volumes – are calculated on the basis of these capacities. Any major and systematic discrepancies between capacity-related export quotas and actual cross-border flows based on commercial transactions, interfere with secure operation on neighbouring networks. Such discrepancies affect not only the supply situation in Italy, but also those in the cantons of Ticino and Valais, as well as to some extent in Grisons (e.g. in the Upper Engadine region).

The Swiss authorities have been almost entirely excluded from the procedure for allocating volumes of electricity exports to Italy: it is only the proprietors of Switzerland's transmission network who have been included in the negotiation process to date. One of the consequences of this was that regulators of Italy and France agreed on a capacity allocation in December 2001 without including Switzerland in the decision-making process.

The resulting agreement, which was effective for 2002, allocated the French network operator an export volume of 2,600 MW, which was equivalent to an increase by 400 MW. By contrast, Switzerland's network operators were only allocated an export volume of 2,800 MW, which was equivalent to a reduction by more than 400 MW versus the previous physical flows recorded at the border between Switzerland and Italy. And versus the agreed export quota for 2001, this meant that Switzerland's network operators were deprived of control over a volume of 300 MW. By way of justification for this solution to the sole detriment of Swiss network operators it was stated that Switzerland has not implemented the regulations of the European guidelines on the single electricity market, in particular the separation of network operation from power plant operation and trading. This ruling was contested in Italy in the form of an administrative law appeal. Switzerland's network operators and the Italian regulatory authorities were subsequently able to reach a mutually acceptable solution within the scope of settlement proceedings. But the same problem associated with this allocation procedure has recently arisen again in connection with the allocation of capacities for 2004. In the judgement of the Swiss Authorities, decisions taken in this way have a negative impact on security and reliability. What is therefore required is a transparent procedure that focuses solely on ensuring the safe and reliable operation of the system – and on top of this, the relevant Swiss authorities have to be incorporated into the decision-making process.

## 1.4 New regulations on the European electricity market

Ever since the electricity market guidelines – which call for the separation of operation of the transmission network from operation of power plants and trading – came into effect in 1997, load flows have been deviating more and more from the previously known patterns. This means that new regulations are required that are fundamentally based on those of the UCTE, but are also legally enforceable. Proposals put forward to date by ETSO (the European organisation of transmission network operators) called for the introduction of fairness rules until such time as new legal provisions enter into effect throughout the EU<sup>4</sup>. The idea here is that operators of transmission networks would not enter into transmission service contracts that give rise to unscheduled electricity flows on the networks of other operators. Fairness rules of this kind take on particular significance when electricity flows concern existing bottlenecks on other networks. For this reason, measures aimed at mutual co-ordination should be carefully examined before such contracts are concluded. Although the ETSO has urgently recommended the observation of such fairness rules until the relevant legal provisions come into effect, as far as the transmission capacities to Italy are concerned the solutions that have been found to date remain inadequate.

In the meantime, the adoption of the EU directive on conditions of network access for cross-border electricity trading (1228/2003) on 26 June 2003 means that a legal framework now exists at the EU level for turning such regulations into legal provisions. The directive states that transmission network operators are obliged to mutually co-ordinate activities and exchange information in order to guarantee network security and reliability within the scope of congestion management, and that the calculation of export volumes has to be based on transparent models. Furthermore, network operators are required to publish their available transmission capacities a day in advance. The EU Commission has been granted the authority to issue guidelines for the enforcement of this ordinance. These are to include regulations governing security standards, plus rules concerning network usage and operation. The EU ordinance is due to come into effect on 1 July 2004.

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<sup>4</sup> ETSO statement on transmission service contracts, November 1999

During the preparatory stage for the EU ordinance, the ETSO carried out some important studies on the topic of capacity allocation – for example, with its paper entitled “Co-ordinated congestion management, an ETSO Vision” that was released in February 2002. If the EU Commission were to implement the concept outlined in that study, it would be necessary to allocate commercial supplies in such a way that they would correspond as closely as possible to the effective load flows. It remains to be seen whether these rules will be implemented in a binding manner in the single European market, and if so, when.

From Switzerland’s point of view, the implementation of such provisions is something to be fundamentally welcomed. However, the relevant Swiss authorities would have to be included in such decisions. Corresponding regulations will therefore also have to become an integral part of formal agreements between Switzerland and the EU concerning the single European electricity market. This concerns both the interim solution to be negotiated between Switzerland and the EU, as well as the future definitive legal provisions to be anchored in the electricity industry ordinance. The present-day method of allocating international electricity exports to Italy is unsatisfactory as well as unsuitable for adequately meeting the security and reliability requirements in a similar situation to that which arose on 28 September 2003.

## 2 Incident of 28 September 2003

### 2.1 Sequence of events

Table 1 describes the sequence of events on 28 September 2003 according to ETRANS, the UCTE, GR<sup>5</sup> and other sources.

Table 1: Sequence of events on 28 September 2003

Timeframe	Time	Occurrence
Prior to failure of Lukmanier line	22.9.2003 to 28.9.2003	Occurrence of systematic discrepancies (mainly excess loads) on transit and border transmission lines between Switzerland and Italy, especially at night, between contractual volumes of electricity exports (Switzerland-Italy) and effective physical flows.
	28.9.03, 3 a.m.	Italy indicates a very low load (total, 27,702 MW, of which 3,628 MW pump load) versus its peak daily demand. Loads on transmission lines between Switzerland and Italy are very high (3,610 MW). Generally speaking, Italy currently imports approximately 24% of its electricity supply, primarily from Switzerland and France. Loads on the transit and cross-border transmission lines between Switzerland and Italy are approximately 550 MW too high compared with the export volume (Switzerland-Italy) of 3,050 MW. Italy imports approx. 300 MW too much versus the agreed total import volume of 6,400 MW. Both these factors result in a greater load than planned on transit lines through Switzerland. Weather in Altdorf (approx. 10 km south of incident site): wind, 8 km/h; temperature, approx. 15° C.
Failure of Lukmanier line	28.9.03, 3.01 a.m.	Failure of Lukmanier line following flash-over between conductor cable and a tree (line to ground fault without contact of cable and tree); visible consequences in ETRANS and GR <sup>5</sup> control centres: sharp flow decline on LAVORGO-MUSIGNANO cross-border line (from 1,328 MW to 547 MW).
After failure of Lukmanier line, but prior to failure of San Bernardino line	28.9.03, 3.02-3.08 a.m.	Failed attempts to restore Lukmanier line; exchange of information between ETRANS, ATEL Dispatching and EGL; failed attempt by ATEL to restore Lukmanier line (reason: phase angle differential too great)
	28.9.03, 3.10.47 a.m.	Phone call from ETRANS to GR <sup>5</sup> : Lukmanier line down, San Bernardino line overloaded. ETRANS requests GR <sup>5</sup> to adjust import flow plan by 300 MW, i.e. compliance by GR <sup>5</sup> with agreed plan for the period from 3 a.m. to 4 a.m. (existing discrepancy, approx. 300 MW).
	28.9.03, 3.21 a.m.	Italy's import volume now at agreed level of 6,400 MW. However, significantly higher levels had been detected beforehand. Immediately thereafter, increasing volume of imports into Italy until blackout.
Failure of San Bernardino line	28.9.03, 3.25 a.m.	Failure of San Bernardino line following flash-over between a conductor cable and a tree (line to ground fault without contact of cable and tree); weather in the region (vicinity of Sils): temperature, approx. 7 °C, wind strength, 30-40 km/h.
Immediately following failure of San Bernardino line	28.9.03, 3.25-3.27 a.m.	Cascading effect: failure of other transmission lines to Italy. At 3:27, total blackout in Italy.
Blackout in Italy followed by power failures in border regions of Switzerland	28.09.03 3.27 onwards a.m.	Power failures in parts of Switzerland (Ticino, Upper Engadine, areas of Valais, suburb of Geneva). The causes vary, but all power outages are associated with the blackout in Italy: for a short time, no supply of electricity possible to Ticino and Upper Engadine, neither from Italy nor from northern Switzerland. In Valais, a number of power plants had to be shut down for security reasons (occurrence of brief power surges). As a result, it was no longer possible to supply power to the Obergoms region. Near the city of Geneva a transformer automatically triggered a shutdown due to voltage surges occurring immediately after the blackout in Italy. As a consequence, approximately 10,000 inhabitants of Geneva were without power. Electricity was restored to the affected areas of Switzerland within 1 to 1.5 hours (except the San Bernardino region, where lengthy interruptions continued to occur until Sunday afternoon).

<sup>5</sup> GR<sup>5</sup> ([www.grtn.it](http://www.grtn.it)): "GR<sup>5</sup> (Gestore della Rete di Trasmissione Nazionale - Italian independent system operator) ... aiming at fostering liberalisation and competition in a sector of strategic importance for economic development."

## 2.2 Interim report of the UCTE

The report by the UCTE cites four main reasons for the blackout, as outlined below.

### 2.2.1 Problem of restoring the Lukmanier line

The **UCTE** ascertained that protective gear prevented the restoration of the Lukmanier line because the phase angle differential<sup>6</sup> was greater than the critical threshold of 30°.

Comments by **ETRANS**:

- A reference load flow serves as the basis for specifying volumes of electricity exports to Italy for traders in France and Switzerland.

**Table 2:** Comparison between reference load flow in winter 2003 and load flow on the Lukmanier line on 28 September 2003 at 3 a.m.

	Time	Loading on Lukmanier (2,400 A)	Phase angle differential, Lukmanier	Phase angle differential after failure of Lukmanier line
		[%]	[°]	[°]
Reference load flow	Winter 2003	47	10	20
Prior to blackout	28 Sept. 2003, 3 a.m.	86	18	42

Table 2 shows that, at 86%, the flow on the Lukmanier line just prior to the events leading to the blackout ("Loading" column) was well above the reference load flow of 47%. Flows in the network and on transmission lines depend on how much power is injected and how much power is taken out, and where. How much power is injected depends on trading operations. However, the location at which power is injected, which serves as the basis for the reference load flow, may in practice be somewhere else. This may give rise to unscheduled power flows.

- According to the UCTE report, the effective load flow at 3 a.m. was safe (N-1). But to maintain this status it is necessary to take corrective measures immediately after the failure of the transmission line. In the event of a failure on the Lukmanier line, the operator normally takes two separate steps: Firstly he tries to lower the current on the remaining transmission line – the San Bernardino transit line – from 110% to 100% (100% is permissible in permanent operation) as quickly as possible. After failure of the Lukmanier line, and up to the time of restoration of 100% load on all remaining transmission lines, it is crucial that no further critical incidents occur. This procedure corresponds to the regulations laid down by the UCTE.<sup>7</sup>
- As soon as the load on the San Bernardino line has been reduced to 100%, the operator may proceed to the second step, namely returning the network from N security status to N-1 by restoring the Lukmanier line. Since the phase angle differential on this (deactivated) line has to be less or equal 30°, the operator first needs to reduce the transit flow through Switzerland to Italy.

<sup>6</sup> A phase angle differential is a normal electro-technical phenomenon in AC operation. It represents the time span between zero-axis crossover of the sinusoidal alternation on any two bus bars of an electricity network. This time span is converted and expressed as unit [°]. Generally speaking, large flows between two bus bars give rise to greater phase angle differentials. As a rule, an outage gives rise to greater phase angle differentials over the interrupted line when the total flow over the remaining parallel network remains unchanged.

<sup>7</sup> N-1 security: if a network component (e.g. a feed or conductor) should fail, it must be possible to maintain operation with the remaining components without a resulting supply failure, overload or other interruptions. With "N" security, any further incident may lead to a supply failure.

Assuming that GRTN correctly adheres to the import plan, this can be achieved without difficulty; for this purpose, GRTN would have had to switch off major pump loads. Furthermore, RTE<sup>8</sup> would have had to rearrange electricity production (locations and volumes) in France – and possibly in Eastern Europe – intended for commercial export to Italy so that the transit network through Switzerland would have supplied approx. 500 MW less to Italy.

Comments by **SFOE**:

- Table 2 shows that, with the safe reference load flow in winter 2003, the critical phase angle differential over the Lukmanier line is well below 30°. If the locations and power injection volumes for exports to Italy had been adhered to as specified in the reference load flow, on 28 September 2003 the phase angle differential over the Lukmanier line would have been below 30° after its failure. This would have made it possible to restore the transmission line and thus prevent the occurrence of the subsequent incidents on 28 September.
- The ETRANS operator contacted GRTN in order to initiate the first step (see above). He duly notified his counterpart that Italy's import volume was currently approximately 300 MW too high. By instructing GRTN to adjust this error, the ETRANS operator wanted to lower the load on the San Bernardino line to 100% (cf. phone call between ETRANS and GRTN, Section 2.2.2).
- But apparently this first step was not taken quickly enough by GRTN. It appears that GRTN would have been able to attain the scheduled load very quickly by switching off nearby pumped storage power plants that were currently operating in pump mode. Although the scheduled load was in fact attained at 3.21 a.m. (i.e. after 10 minutes), the import volume rose again almost immediately afterwards. Since this first step took too long to implement, the load on the San Bernardino was not eased quickly enough and the sustained heat-up caused a pronounced sag, thus increasing the likelihood of another failure (e.g. due to line to ground fault). For this reason, it was not possible to initiate the second step (i.e. restoring the Lukmanier line after the pumps had been switched off in Italy, and reorganising production in France) at all.
- This second step (see above) is justified: In a trilateral agreement between France, Switzerland and Italy it was decided to specify the hourly export volumes for winter 2003 as follows: Switzerland to Italy, 3,050 MW / France to Italy, 2,650 MW. At 3 a.m. the actual total physical flow through Switzerland to Italy was 3,610 MW, while that between France and Italy was 2,212 MW. Measured at the border between Switzerland and Italy, the export volumes from Switzerland were thus approximately 550 MW too high, while those from France to Italy were 438 MW below the agreed level. Studies need to be carried out in order to determine whether (and how) France will be able to redistribute physical flows in the future by reorganising production both at home and elsewhere in Europe so that the load on the transmission lines through Switzerland can be reduced by approximately 500 MW, and the terms of the trilateral agreement can thus be complied with.
- According to information in the possession of the SFOE, there are no regulations in existence today that govern the local production of electricity for export purposes so that it is possible to adhere to the specified reference load flow. This lack of regulation governing local production in Europe for export to Italy to secure compliance with the specified reference load flow gives rise to unscheduled transit flows via Switzerland's network.

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<sup>8</sup> RTE: Gestionnaire du Réseau de Transport d'électricité (network operator in France)

### 2.2.2 Phone call from ETRANS to GRTN

According to the **UCTE**, a phone call between ETRANS and GRTN at 3.11 a.m. demonstrates that, in the period from 3.01 to 3.11 a.m., there was “insufficient awareness of the urgency of the situation caused by the overload on the San Bernardino transit line”.

Comments by **ETTRANS**:

- Immediately after the failure of the Lukmanier line, ETRANS took the prescribed steps to eliminate the problem in accordance with the relevant internal checklist. This checklist was drawn up by ETRANS after the occurrence of a similar incident in September 2000, and following trilateral discussions between the operators of the transmission networks of Switzerland, France and Italy.
- ETRANS informed GRTN by telephone that the Lukmanier line had shut down and that GRTN should adhere to the schedule (i.e. adjust the overload of approx. 300 MW). ETRANS does not have a tape recording of this conversation.
- At the critical moment, GRTN had a pump capacity of 3,638 MW on its network, more than 300 MW of which could have been switched off in less than 10 minutes in order to reduce the overload.
- In their network control centres, both GRTN and ETRANS have online access to the same data concerning cross-border electricity flows. The sharp change in flows that was registered at 3.01 a.m. on the Lavorgo-Musignano line was clearly recognisable for both operators. These online data provide adequate pointers to the occurrence of a critical incident in Switzerland. It appears that GRTN did not interpret the signals correctly.

Comments by **SFOE**:

- The cited phone call clearly took place since Italy’s electricity import volume was adjusted by GRTN within 10 minutes (3.11 to 3.21 a.m.) according to the instructions of the ETRANS operator.
- Without a tape recording, the SFOE is unable to assess the content of the phone call from ETRANS.
- The UCTE report does not state whether GRTN proceeded in accordance with a checklist following the failure of the Lukmanier line in the same way as ETRANS. However, it has to be assumed that GRTN monitored the situation very closely, since the network state was potentially critical and approximately 25% of Italy’s consumed capacity was being imported.

### 2.2.3 Instability of the Italian network

The **UCTE** refers to the problem of instability of the Italian network and a voltage drop in the Italian network, even before Italy was electrically separated from the remainder of the UCTE.

Comments by **ETTRANS**:

- ETRANS is not sure whether Italy’s network is being operated in accordance with the UCTE guidelines concerning general protective measures and plans for the prevention of major interruptions.
- In the view of ETRANS, it would have been possible to prevent the blackout in Italy even after the failure of both transit lines if there had been adequate preventive measures (e.g. sufficient voltage stability) in place in Italy.

Comments by **SFOE**:

- The instability of the Italian network shortly before the blackout demonstrates how important it is to closely monitor the status of the network and quickly take corrective measures following an incident.
- In the future, network operators within the UCTE also have to demonstrate to their national authorities (e.g. through studies) the extent to which they are able to meet the UCTE guidelines for independent isolated operation at any time. Here it is especially important to examine whether the network operated by GRTN is capable of isolated operation, and whether the cascade-style failure of other transmission lines on 28 September occurred as the consequence of inadequate measures to maintain stability.

#### **2.2.4 Distance between conductor cables and trees**

The **UCTE** states that it is possible that the provisions governing the minimum distance between high-voltage transmission lines and trees were not complied with. It goes on to describe this issue as a matter to be investigated by the countries concerned.

The Federal Inspectorate for Heavy Current Installations (**Inspectorate**) comments on this in a separate report:

- While flash-overs to trees from overhead high-voltage transmission lines occur from time to time, they are less common at the levels of 220 and 380 kV. Over the past ten years, Atel Netz AG registered five flash-overs to trees from its ultra-high-voltage network. Over the past three years there have been five identified and four suspected flash-overs to trees from the ultra-high-voltage network of EGL Grid AG. As far as its nature is concerned, the incident that occurred on 28 September 2003 is therefore nothing out of the ordinary.
- Atel Netz AG and EGL Grid AG both carried out internal inspections, including in particular timber controls (checking the vertical distances between trees and uncovered conductors of overhead high-voltage transmission lines based on a conductor temperature of 40° C), in accordance with the relevant regulations and standard practice. The reports on these inspections are clearly formulated and describe the various precautionary measures to be taken.
- The Inspectorate carried out its supervisory duties in accordance with the legal requirements, and did not identify any infringements of security regulations on the part of the two operators concerned. In the meantime it has proven necessary for the Inspectorate to improve its documentation of its inspections.
- In view of the growth of international electricity trading, there is an increasing tendency to load high-voltage transmission lines to their capacity limits (and even to overload them for short periods). It is essential that operators of these networks bear the fact in mind that these practices must not be carried out at the expense of operating security of electricity transmission lines.

Comments by **SFOE**:

- It should be noted that the load on the transit lines was approximately 550 MW higher than the scheduled export volume to Italy, and that at the same time an import discrepancy of 300 MW on the GRTN network enhanced the impact on transit flows. As a result, the conductor cable sag was increased beyond the specified limit and thus the likelihood of occurrences such as flash-overs was also increased. On 28 September, no storms were observed in the vicinity of the Lukmanier and San Bernardino transmission lines that could be regarded as the cause of line to ground faults (cf. Section 2.1).

## 2.3 Points cited in the interim report by the UCTE that need to be clarified

The interim report by the UCTE deals with the sequence of events in the period from 3.01 to 3.25 a.m. It confirms that in the period prior to 3 a.m., ETRANS was operating its network in N-1 security status. The four main reasons for the blackout are derived from the behaviour of the involved players.

In its report, the UCTE cites a variety of points that need to be clarified through in-depth studies. The SFOE regards the matters raised by the UCTE as very important and shares the opinion that they should be carefully examined. The following issues still need to be clarified:

- What was the reason for Italy's import discrepancy at 3 a.m.? Which steps did GRTN take at which locations in order to adjust the import discrepancy of 300 MW? Why did it take GRTN so long to make the adjustment? Which transmission lines of the countries exporting electricity to Italy were relieved of a total of 300 MW during this period? Why were pumps in pumped storage power stations in Italy not switched off sooner?
- According to ETRANS, the import volume to Italy was close to the scheduled level of 6,400 MW at approximately 3.21 a.m. This level was reached within 10 minutes by reducing the import from approximately 6,700 MW. Why did the overall import volume rise again almost immediately afterwards (between 3.22 and 3.25 a.m.)?
- How does GRTN process the online data concerning the Swiss and French networks that are constantly transmitted by ETRANS?
- Do GRTN and RTE each have a checklist regarding behaviour in critical network situations in the border regions between France, Italy and Switzerland? If so, what are the steps they describe for responding to critical situations? If all three operators use a checklist, have they been co-ordinated with one another? What information tools do GRTN and RTE use in order to independently identify a critical situation?
- To what extent would it have been possible on 28 September 2003 at 3 a.m. to reorganise production of French traders in such a manner as to significantly lower the loads on the transit and cross-border transmission lines between Switzerland and Italy?

## **3 Duties and behaviour of the Swiss authorities**

### **3.1 National economic supply and communication between authorities and the electricity industry**

#### **3.1.1 National economic supply**

In accordance with the Federal Law on National Economic Supply, the Delegate for National Economic Supply and the organisation that answers to him (Federal Office for National Economic Supply) are obliged to take the necessary precautions to secure the national supply of essential goods and services in the event that the economy is no longer able to do so itself. Electricity belongs to the category of essential goods.

In the area of national economic supply, the energy sector and industry specialists from the Electricity Section have defined energy management measures to secure the supply of electricity at a lower level in the event of shortages (insufficient energy or capacities). The initial stage involves appealing to the population to voluntarily limit consumption. If this does not yield the desired result, the next step is to impose compulsory restrictions. Consumption may also be reduced further by switching off networks and allocating quotas. This section is also required to constantly monitor and analyse Switzerland's electricity supply. If there are strong indications of supply shortages, or if such a situation has already arisen, the next step is to call on OSTRAL, an organisation entrusted with the task of securing electricity supply in extraordinary situations. OSTRAL comprises representatives of the electricity industry, each of whom is fully acquainted with the various management measures.

In August 2003, the Commission of Swiss Network Operators approved a set of guidelines concerning communication in the event of problems on Switzerland's ultra-high-voltage network. These guidelines regulate the exchange of information among transmission network operators as well as between the latter and ETRANS that is currently carried out in an informal manner. In addition, any problems of national scale that arise on the transmission network will now be reported by the National Alarm Centre to cantonal and urban police authorities, the federal authorities and the media. If less than three stations are involved, the National Alarm Centre will only report such problems if they last longer than 1 hour.

#### **3.1.2 Notification of the authorities following the incident on 28 September 2003**

On 28 September the General Secretariat of the Federal Department of Environment, Transport, Energy and Communications (DETEC) alerted the stand-by service of the Swiss Federal Office of Energy on the basis of media reports. In the course of the same day, the SFOE drew up a picture of the situation for itself by contacting the involved electricity companies. It also answered questions from national and international media, or passed them on to an information centre set up by the electricity industry. On 29 September the Energy Section of the Federal Office for National Economic Supply carried out an assessment of the situation headed by the SEL, and found that the Swiss electricity industry was able to deal with the problem itself. It therefore decided that no further action was required.

In accordance with the new strategy concerning national economic supply, crisis teams primarily have to be called into action in the event of short-term to medium-term interruptions to supplies. With network failures, it is not possible to judge in advance how long they may last and in which ways they may lead to further-reaching consequences. For this reason, the relevant authorities in the area of national economic supply, and those within DETEC (press office and SFOE), need to be in the position

to carry out an assessment of the situation and closely monitor ongoing developments immediately after the occurrence of any significant problem on the transmission network. On 28 September, this was only possible to a limited extent. However, this incident showed that the media and the general public expect to receive information from the authorities without delay; and in the event of cross-border incidents, the necessity arises for communication among authorities at the international level.

## 3.2 Assessment of the Federal Inspectorate for Heavy Current Installations in the expertise prepared by the law firm of Binder in Baden

### Mandate

In association with the incidents leading to the blackout in Italy, the Swiss Federal Office of Energy (SFOE) entrusted the law firm of Binder with the task of preparing an expertise concerning the supervisory duties to be carried out by the Federal Inspectorate for Heavy Current Installations (Inspectorate) in the area of ultra-high-voltage networks, and how it has fulfilled these duties over the past few years, both in general and with specific reference to the Lukmanier and San Bernardino transmission lines.

The authors of this expertise came to the following conclusions:

### Supervisory duties of the Inspectorate

#### a. *Within the scope of construction and modification of ultra-high-voltage lines*

*Electricity legislation contains detailed provisions governing the construction and modification of high-voltage installations (planning approval procedures). The Inspectorate is the initial licencing authority, and for each project it is required to carefully examine whether the plans meet the legal provisions. This form of supervision is supplemented by an inspection obligation. Each new or modified installation is subject to inspection. Here the Inspectorate has to verify that the installation concerned meets all legal requirements and fulfils the conditions stated in the permit or licence.*

*The Inspectorate bases its inspections of new and modified installations on precisely defined procedures, and on the basis of documents at our disposal we were able to determine that it adheres strictly to these procedures and the relevant legal provisions. We also closely verified compliance with regulations governing the permissible distances between conductor cables and buildings, the ground and fences. Its reports also cite the measures still to be taken by proprietors of installations, plus any documentation that still has to be submitted. The Inspectorate fully performs its duties relating to preventive supervision in the area of ultra-high-voltage transmission lines in accordance with its mandate. In some cases, it contractually assigns the approval of other high-voltage installations to Electrosuisse, and in our view this is not permissible.*

#### b. *Supervision of existing ultra-high-voltage transmission lines*

*By contrast, the regulations governing the supervision of already existing and approved high-voltage installations are somewhat rudimentary. This form of supervision is based on the principle that transmission companies operate their installations on their own responsibility and have to regularly inspect them themselves. As a body within an industry association (Electrosuisse) that is independent in terms of both structure and personnel, the Inspectorate is obliged to fulfil the mandate entrusted to it by the federal government of acting as supervisory authority for high-voltage installations. This mandate involves periodical inspections alongside taking action in response to reports of specific events or incidents.*

*The Inspectorate's periodical inspections of high-voltage installations (in the 220/380 kV range) take place within the scope of existing periodical contacts with proprietors of ultra-high-voltage networks (in association with planning approval procedures, inspections of new installations, information about future projects). It does not carry out separate periodical inspections solely for this purpose. Its inspectors obtain an overview of the status of installations in the 220/380 kV range within the scope of various periodical contacts with the proprietors of ultra-high-voltage networks, and are thus able to make an assessment within the scope of their supervisory duties. However, we found that the written documentation of these inspection activities was inadequate. Clear and comprehensible inspection reports form an integral part of its supervisory duties, and greater attention needs to be paid to this aspect.*

*We were able to verify the general fulfilment of material supervisory duties by the Inspectorate through various discussions, and fulfilment of its duties relating specifically to the Lukmanier and San Bernardino transmission lines by studying the relevant documents. The Inspectorate assigns periodical inspection activities relating to other power apparatus installations which are not operated at ultra-high-voltages, to Electrosuisse, and in our view this is not permissible.*

## 4 Conclusions and recommendations

### 4.1 Conclusions

The main causes of the incident that occurred on 28 September 2003 are the unresolved conflict between the trading interests of the involved countries and companies, and the technical requirements of the existing transnational electricity system. Present-day standards and legal instruments are lagging well behind economic realities.

Italy's electricity imports have risen sharply over the past few years. The main reason for this is the pronounced difference in wholesale prices between Italy and those countries that usually produce surpluses. Italy's imports are mainly transmitted via the high-voltage networks of France and Switzerland.

In order for these volumes to flow smoothly, it is essential that all technical requirements are complied with:

1. The actual load must not deviate significantly from the agreed volume.
2. Congestion occurs on transmission lines between Italy and its northern neighbours, and this means that the often limited capacities have to be allocated to traders in such a way as to ensure that the networks are not subjected to overloads.
3. The production of electricity intended for export to Italy needs to be monitored so that power injections into the high-voltage network do not lead to excessive, unscheduled load flows, including on the Swiss network.
4. In Italy, as well as in other countries, it is important that adequate production capacities are held in reserve in order to secure a balance between production and consumption by switching power plants on and off as necessary.
5. Network operators in Switzerland and abroad have to work closely together on the basis of recognised and binding regulations.

These technical prerequisites were not met on 28 September 2003.

The blackout indicates the urgency for developing and implementing international electricity trading regulations, and for co-ordination among network operators so that security and reliability can be assured at all times. All network operators must adapt their IT infrastructure and network technology to the latest status of science and technology with the aid of corresponding analysis and optimisation programs.

The binding implementation of recognised principles – such as those laid down by the EU in its ordinance on conditions of network access for international electricity trading, which was approved on 26 June 2003 – is of equal importance.

As a result of the rejection of the Electricity Market Act by the Swiss electorate on 22 September 2002, the authorities and the electricity industry in Switzerland lack the prerequisites for functioning as an equal partner with respect to the development, co-ordination and binding enforcement of electricity trading regulations. Switzerland does not have any sector-related regulatory authorities that could represent the interests of our country in the relevant committees and bodies (CEER) with respect to allocation of cross-border network capacities, negotiation of remuneration for use of the network, etc.

The blackout in Italy has also revealed a sensitivity to the problem of crisis prevention within Switzerland. Interruptions also occurred on 28 September 2003 in areas of southern Switzerland bordering on Italy, but Switzerland's electricity industry was able to restore power without undue delay. In the same way as in other countries, this incident raises questions concerning the effectiveness of existing crisis prevention measures, the capability of our power supply to function on an isolated basis, and the adequacy of production reserves for sustained operation. The situation in Switzerland is relatively favourable, thanks to adequate production capacities, a large number of cross-border transmission lines and a high network density.

In the future, overcoming network interruptions and informing the general public should primarily be the responsibility of the network operator(s) concerned. But the communication guidelines of the electricity industry should also be reviewed and implemented as quickly as possible in order to improve the flow of information to the authorities. The co-operation between sections of the Federal Office for National Economic Supply, OSTRAL and DETEC/SFOE also needs to be reviewed, as do the effectiveness of decision-making procedures and the foreseen measures for handling crises.

## 4.2 Recommendations concerning Switzerland's foreign relations

(1) The SFOE welcomes the measures foreseen in EU ordinance no. 1228/2003 on the conditions governing network access for cross-border electricity trading. The new provisions should be based on the existing UCTE regulations, and should allow no compromise when it comes to security. We also welcome the efforts on the part of the UCTE to adapt the existing regulations to the new requirements on the single market, and to ensure that they are duly complied with. The Swiss authorities also recommend associated efforts on the part of ETSO.

(2) The Swiss authorities would welcome the opportunity to actively participate in the formulation of the guidelines in accordance with the provisions of EU ordinance no. 1228/2003. Switzerland's inclusion should take place regardless of the fact that it is not a member of the EU. Fair and transparent procedures are essential for secure supply not only in member states of the EU, but also in Switzerland.

(3) The Swiss authorities would like to have a right of co-determination in the procedures for allocating capacities for export to Italy, alongside the Italian and French regulators. The Swiss authorities reject in principle any solutions that negatively affect supply and transmission security in Switzerland and its neighbouring countries.

(4) The Swiss authorities recommend proprietors of Swiss transmission lines to voluntarily align themselves with the organisational requirements on the single European market as quickly as possible. Establishing a Swiss network operator as an independent entity would be an important step here.

The roles of regulators and authorities in Europe and Switzerland, of players on the market (traders) and of network operators still part of monopolistic electric utilities need to be clarified as quickly as possible. In Switzerland's view, binding regulations in the following areas are of the highest priority:

- **Guaranteeing a high degree of network-related supply security** and monitoring compliance with these regulations.

Regulations aimed at maintaining network security need to encompass the options of instantly changing the location of excess production, switching off loads (pumps), adapting the network topology and the immediately resulting changes to physical flows in order to prevent overloading network components.

- **Allocation of volumes of electricity for export to Italy** and monitoring compliance with these regulations.

These regulations have to take into account the variability of maximum transmission line loads throughout the year (temperatures, wind speeds), fluctuations in consumption and the type of production at any hour of day throughout the year. Competitive procedures (auctions) for allocation of transmission capacities need to be co-ordinated with transmission security aspects.

- **Minimum reserve production capacities** in the various UCTE regions, and monitoring of compliance.

These regulations have to take into account the degree of flexibility of changes in production, readiness for production at any time, and place of production.

- **Financial compensation for eliminating network congestion.**

This concerns elimination of short-term network congestion and the resulting cost of corrective measures associated with electricity production, and the maintenance and expansion of regional and major transit lines through Switzerland in order to eliminate congestion over the longer term.

## 4.3 Recommendations concerning Switzerland

(1) The SFOE regards the incident of 28 September 2003 as a sign that there is an urgent need for comprehensive legislation governing the electricity market. Switzerland needs a strong sector-related regulatory authority that secures non-discriminatory network access, the allocation of transmission network capacities in line with the existing physical prerequisites and adequate compensation for use of the network. It needs to ensure that a reasonable proportion of earnings from network operation flow into expansion and maintenance tasks, as well as safe operation. This authority has to supervise network operation and intervene as necessary in the event of inadequate network security and insufficient investments.

With an electricity industry ordinance that is co-ordinated with the developments in Europe, Switzerland will be able to preserve its function as an electricity hub and a major producer of hydroelectric power.

(2) An increase in the frequency of power failures also raises questions of a scientific nature. Research centres specialising in network-related issues – especially the two Federal Institutes of Technology – are to be asked to participate in the scientific handling of issues relating to electricity networks in Europe.

(3) The following measures should be taken, based on the report by the Federal Inspectorate for Heavy Current Installations (Inspectorate):

Issue of an internal directive aimed at ensuring that all inspection activities are documented in a way that makes them readily comprehensible (deadline: 31 December 2003).

All operators of ultra-high-voltage networks are to be instructed by the Inspectorate to carefully check the load flows on conductors (some operators have already begun doing this). Conductor temperatures need to be re-specified, and in the event that these should significantly exceed 40° C in normal operation, the permissible degree of sag at critical points will need to be re-assessed (deadline: 31 March 2004).

The Swiss Federal Office of Energy should examine whether the assumptions adopted in Article 47 of the Ordinance on Electricity Transmission Lines for calculating the maximum anticipated degree of sag of a conductor, are still correct (deadline: 30 June 2004).

(4) One of the findings resulting from the expertise prepared by the law firm of Binder (Merker/Rey) was that the Inspectorate contractually assigns certain approval procedures and periodical inspections to Electrosuisse, which is not permissible.

Comments by SFOE: When the Electricity Act was finalised in 1902, the federal authorities deliberately assigned authority for the inspection of electrical installations to the already existing high-voltage inspectorate of Electrosuisse (at that time, Swiss Electrical Engineering Association). In this way it was possible to make use of the available know-how, and there was no need to establish a new federal authority. The problems that arise from this form of co-operation between federal authorities and private-sector institutions are well known. For this reason, a variety of measures have been taken since 1998 in order to bring about a clearer separation of the duties of the Inspectorate and Electrosuisse. The Inspectorate has been instructed to make the necessary organisational and personnel adjustments by 30 September 2004, so that all sovereign tasks can be performed by staff of the Inspectorate. DETEC is to determine whether any additional changes are required in association with the preparation of the new federal legislation governing compliance with security regulations.

(5) In association with national economic supply, the SFOE recommends reviewing the flow of information between network operators and federal government crisis organisations. The SFOE wants to intensify its systematic and permanent observation of the market as quickly as possible. The degree of co-operation between the Federal Office for National Economic Supply, the SFOE and OSTRAL also needs to be studied.

(6) DETEC and the SFOE are examining the possibility of introducing an urgent decree aimed at establishing the necessary institutions and competencies for guaranteeing a secure electricity supply in Switzerland and enabling Switzerland to have a say on the European electricity market. The associated experts commission is to issue a statement of position on 16 December 2003 concerning the suitability of this procedure and the various elements to be incorporated into the decree (regulator, Swiss network operator, degree of market liberalisation). The decree would enable a regulated transition until the introduction of a comprehensive electricity industry ordinance.

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