Reliability of Supply in Liberalised Power Markets*

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Background

This paper builds on the results obtained by the Tacis financed project "ERUS 9902 Rationalisation of the Federal Wholesale Electricity and Power Market – "FOREM". This project is in its final stage and was undertaken by KEMA in close cooperation with RAO-UESR (namely the Federal Network Company and System Operator). Amongst other items this project covered the Technological Rules for the Wholesale Market in Russia.

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Introduction

Specialists in the power sector in many countries including those preparing for the transition towards liberalised electricity markets have regularly been expressing their concerns about the dangers of a reduction in the existing levels of reliability of supply. The Californian power crisis and, more recently, larger blackouts in North America and Western Europe have further fuelled these concerns. Many claim that liberalisation is one of the reasons for these disturbances. Firstly, market participants force System Operators (SO) to operate their systems closer to their limits. Secondly, network companies might be subject to price cap regulation so that they lack the incentives to maintain and invest in the networks. Thirdly, it is questioned whether power markets provide sufficient incentives to Generators to invest in new power plants. Finally, which entities in the unbundled power industry carry the responsibility for guaranteeing reliability of supply – when responsibility is not clear it often results in no one party being responsible.

This paper:

! Explains who is responsible for maintaining the established level of reliability and the role of market participants and state regulators under the conditions of liberalised electricity markets.

! Clarifies how reliability is impacted on by liberalisation and the role of the regulator in quality regulation and Grid Codes is explained. It also explains the instruments that are available for Quality of Supply Regulation.

! Discusses how the adequacy of installed generating capacity can be maintained in a market environment.

! Gives a short summary of some recent blackouts in Europe and North America and analyses the causes.

! Analyses how reliability of supply is maintained in the new industry structure and wholesale market in the Russian Federation and considers what lessons can be drawn from the recent blackouts in order to prevent similar blackouts happening in Russia.

Who is Responsible for Reliability?

The responsibility for reliability of supply has been re-allocated over a number of players due to the liberalisation of the industry. In the situation of the vertically integrated utility, all main functions were performed by one utility. Due to the unbundling, this responsibility has been allocated over different companies.

Reliability of supply is basically determined by two elements – firstly reliability of transmission and distribution networks and secondly reliability of the generating system. The 'generation system' is the total of all power plants and not simply the reliability of individual power plants. Reliability however encompasses two aspects –

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firstly security and secondly adequacy, which are defined by NERC[1] as follows:

Adequacy: 'Ability of the electric system to supply the aggregate demand and energy requirements of their customers at all times, taking into account scheduled and reasonably unscheduled outages of system elements'.

Security: 'Ability of the electric system to withstand sudden disturbances such as short circuits or unanticipated loss of system elements'.

This can be illustrated as follows:

Diagram 1

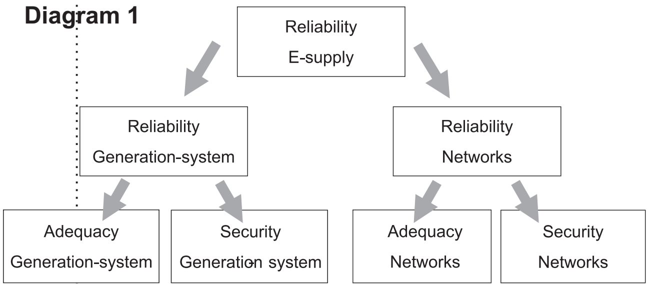
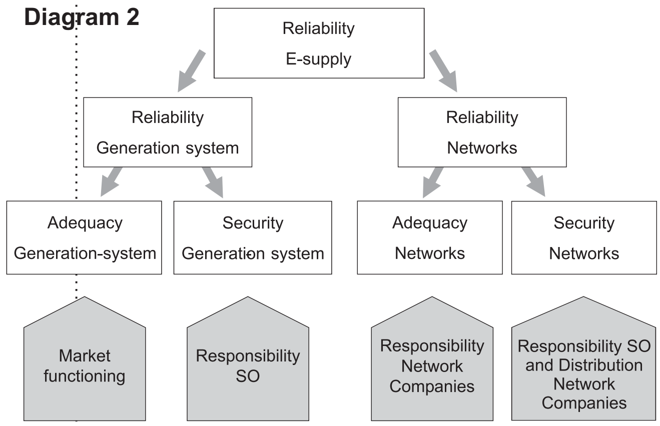


Diagram 2



From an economic point of view security is a public good whereas adequacy of the generation system is a private good [12]. This means that the responsibility for having adequate installed generating capacity available has been passed from the integrated utility to market forces. This aspect will be elaborated in section.

The responsibility for the other three elements – viz security of generation system, adequacy of networks and security of networks – is allocated to certain companies and is not left to market forces. The SO is responsible for security of the generation system. This means that the SO must contract/procure sufficient generation reserve to deal with disturbances. The responsibility for adequacy of networks is allocated to the network companies (for Russia these are the federal network company and the territorial and distribution network companies). They are responsible for the development of adequate transmission and distribution networks. The responsibility for the security of the networks lies with the SO as far as the federal and territorial network companies are concerned. As the operation of the distribution network companies is outside the scope of the SO, the responsibility for the security of the distribution networks lies with the distribution network companies. The result is illustrated in the diagram 2.

This fragmentation of responsibilities requires the establishment of technical rules (viz Grid Codes) to ensure that rights and duties of each of the entities are clearly described and that information exchange and cooperation between the different entities are ensured. These rules normally are part of a larger approach for 'quality regulation' implemented by the regulator.

Quality Regulation – Role of Regulator

Rationale for Quality of Supply Regulation

Even though economic regulation of utilities usually focuses on price regulation, regulators also have to pay attention to performance standards and service quality. The quality of service is just as important to consumers as prices. If standards of service fall but prices remain the same, consumers are effectively suffering an increase in prices. In competitive industries, dissatisfied customers will then either demand lower prices or switch their supplier. Likewise, investors will be less willing to invest if they believe that companies are investing too much or too little in service standards. A monopolistic firm, on the other hand, may try to collect the allowed revenue while reducing product and/or service quality. Even though this may cause additional cost for consumers, the network operator may still be able to gain higher profits. Regulators must therefore act to protect consumers' interests. In short, price regulation generally has to be accompanied by some kind of regulation of quality of supply, with the aim of both avoiding distorted and excessive investment and of preventing a decrease of quality and performance standards. Otherwise, price regulation may give unintended and misleading incentives to quality levels[2].

[1] North American Electric Reliability Council.

[2] In the case of rate of return regulation, utilities are generally free to define their own investments and quality levels. In line with economic theory this tends to create incentives for over-investment in both assets and quality. Not surprisingly, many regulatory regimes therefore focus on preventing this type of inefficiencies and avoiding excessive investments. Simple types of cap regulation, on the other hand, may allow a regulated company to reduce its cost by reducing its quality of supply or by cutting investments, maintenance or personnel with the aim of increasing its profits. Consequently, price regulation may thus also provide incentives for under-investment in the energy networks.

The regulator must ensure that the monopoly transmission network companies make sufficient investment in order to maintain the levels of reliability in their networks.

With electricity supply it is not possible to offer customers differentiated levels of reliability[3] due to the technical characteristics of the network. For example all customers in the same street will receive the same level of reliability if they are connected to the same feeder. Differentiating in price based on the quality supplied could accommodate differences in individual customers' preferences. However this approach is virtually impossible.

Instruments for Quality of Supply Regulation

Considerable elements for regulation of the quality of service are implicitly included in conventional regulatory procedures with respect to licensing, pricing, market and system rules, etc. In addition, the regulatory authority may take further steps to ensure that certain performance and quality standards are met. This may involve prescribing certain standards but the regulator may also have to use financial incentives, leading to the notion of performance-based regulation.

One of the simplest instruments is *public exposure.* The idea is that exposure to public opinion (customers, media, etc.) encourages companies to maintain and if necessary improve quality.

Another method is to use *minimum standards* that come in the form of limits to the number and duration of outages.[4] This may or may not result in a penalty. Usually two types of minimum standards are used – viz Overall Standards and Guaranteed Standards. Overall Standards measure performance at the system level (e.g. customer minutes lost, percentage of customers with an outage, or some aggregated quality index). Their disadvantage is that they only pick up the average performance; there may still be substantial differences between individual customers.[5] This leads to allocation inefficiency due to the lack of the penalties' discriminating power. Individual or Guaranteed standards perform better in this regard as they relate to the level of service delivered to individual customers. Here compensation is given to those who were actually affected by sub-standard performance.

The use of standards but also the use of *technical codes* ('Grid Codes' or 'Technological Rules' in the case of Russia) are possible ways of implementing quality regulation. The technical codes are legally binding documents and must include several types of quality standards. The technical codes not only contain standards but also describe in detail the responsibilities of the different entities and the procedures for all the processes that affect both the network companies and the network users. The advantage of the use of standards in technical codes is that it is possible to include several, detailed standards for the different processes and activities of the SO, network companies and network users. The disadvantage of this approach is that although the codes are binding, it is difficult to monitor whether the different parties actually adhere to the standards of the technical codes. For example, there are normally no financial penalties given if technical standards are not met. Technical codes are normally structured in a Planning Code, Connection Conditions, Operating Code and Balancing – or Scheduling and Despatch – Code. Different aspects related to reliability are included in each of these technical codes [8].

Incentive mechanisms can be seen as an extension of a minimum standard because they introduce a direct link between the company's income (price) and the level of performance (quality). Performance can be measured at different levels ranging anywhere between the system level and the performance delivered to individual customers. The penalty/reward structure maps the level of performance with the financial impact (either a penalty or reward). In principle, the number of structures is infinite but setting appropriate penalty and award levels is a delicate task.

Adequacy of Installed Generating Capacity

As has been explained in section, no entity is directly responsible for maintaining the desired level of adequacy of installed generation. Generation companies have to make their own investment decisions depending on expected market price developments. High prices for electricity provide a signal to attract investment until the profitability of the industry equals that of other activities facing comparable risks.

This topic has been strongly debated, since the Californian power crises. It is questioned whether market forces can provide correct incentives to possible investors. (It is outside the scope of this paper to discuss the market design of the wholesale market in Russia.)

[3] Note that this would not be true for load curtailment contracts that are however not considered here since they relate to the supply side.

[4] Some standards, mainly the technical ones, can be explicitly measured. 'Soft' factors, including procedures for changing suppliers or handling of complaints, are usually evaluated indirectly by measuring customer satisfaction.

[5] Each user has his own particular preferences for quality factors, depending on his circumstances.

The following reasons for different behaviour by generators can be given [11][6]:

- ! Application of price caps (price caps will limit the revenues for generators and will thus discourage investment.)
- ! Risk aversion (This mainly applies to peaking units. Although investments in such peaking units would be economically justified, a risk-averse generator could consider investment in such units too risky related to the limited number of operating hours of peaking units.)
- ! Oligopolistic behaviour of incumbent utilities (Incumbent utilities may under invest in order to raise prices, as long as the barriers to entry are sufficient to block the contestability effect of new entrants.)

Some argue that capacity markets should be developed; others claim that such markets can cause market distortions and are not necessary as futures and forwards can provide similar benefits [5]. Doorman [6] concludes that energy based markets, provide fewer incentives to install peaking units (high variable costs, low capital costs) and that therefore reliability of supply will be lower in peak hours. However, he also concludes that this is not an undesirable effect and that programmes should be developed to improve demand side response to high market prices. A recent report [7], financed by the World Bank, analyses the Californian crises and recommends that developing countries implement less risky market models. It suggests that cost-based spot markets, such as those in Latin America, or alternative trading arrangements to spot markets, such as bilateral trading among multiple buyers and sellers, should be considered for smaller power systems. In general a basic pre-assumption of the liberalisation process is to let market forces work wherever possible.

The role of *a regulator* in this context should then be limited to monitoring the correct behaviour of the market, to increase transparency of the market and to investigate the possibility of abuse of market power [8]. Setting of price-caps and/or capacity payments should preferably be limited to power markets in a transition process.

This also means that the *System Operator* (SO) cannot be held responsible for the adequacy of the generation system. However, the SO can play a role in monitoring generation adequacy. The SO can inform the market about foreseen shortages and surpluses and issue warnings if the need arises. The SO can also prepare and issue an indicative generation development plan.

Recent Blackouts in USA and Europe

The discussion on reliability in liberalised power market has gained increased impetus due to the blackouts in August and September 2003 in the USA and Europe:

Investigations of these recent incidents and the recovery from them are very complex as the causes are far from clear and simple. This is generally the case with major failures. Very few major disturbances have been attributable to a single event but rather they are due to a sequence of events often triggered by an extremely simple single incident. Weather, Human Error, Equipment Maloperation and combinations of these have historically been the most common causes. In the recent incidents the basic causes have been established and most are relatively straightforward.

In the case of Sweden and Denmark, the blackout was caused by the combined outage of a nuclear power plant and a double busbar fault (due to the mechanical failure of one isolator). Normally the system must be capable to cope with each single event (n-1 criterion) but in this case a larger failure was unavoidable after what was a multiple event.

Causes like these, apart from the Denmark and Sweden incident, which is extremely rare, are not a new phenomenon with similar events having taken place many times in the past and in these cases they were avoidable. However although the Denmark and Sweden event was unavoidable the restoration process in Denmark was hampered by failures with the Black start station.

In these recent events the causes may have been simple and trivial but the consequences were not. Politicians blame the power industry for lack of investments, the power industry blame the regulators for unfair cost pressure, the System Operators point at each other for giving insufficient information and consumers try to claim damages but rarely succeed. Here the electricity utility industry has been a victim of its own success. With failures so infrequent customers including other essential infrastructure providers appear to have forgotten that electricity can fail and have paid scant attention to contingency plans to cater for major electricity failures.

Impact of liberalisation

Many have stated that liberalisation is the underlying reason for the recent blackouts. However such statements are often too simplistic and more careful attention is needed. The impact of liberalisation can be analysed from different perspectives: un-

[6] These reasons mainly apply to spot markets where generation (sale) is priced on the basis of energy only.

bundling, market functioning, trade and competition and regulation.

- **Impact of unbundling** – Unbundling has fragmented the responsibility for reliability. However, the impact does not have to be negative. Unbundling has allowed network operators to focus on network reliability and security. Also cooperation between different Transmission System Operators (TSOs) in the UCTE system has improved over the last years. The UCTE has set up a system with daily information exchange to forecast day-ahead congestions at the borders. In the case of Italy, the Italian TSO receives from the Swiss TSO on-line flow data of the most important Swiss transmission lines.
- **Market functioning** – Correct market functioning is important in providing correct and timely signals to investors in new generation capacity. There is a widespread concern that markets will not function properly to the detriment of the adequacy of generation capacity. In both Italy and the UK there were warnings of power cuts because of generation shortages before the incidents in these countries happened. However the incidents itself were not caused by shortage of generation capacity. The same applies to the blackouts in Sweden/Denmark and the USA/Canada.
- **Impact of trade and competition** – The freedom to carry out trading – both intra-state and interstate – has in general been to the benefit of the customer. However this freedom has to be balanced against the requirements of the real world or in this case the real system, which is not infinite. System operators have had to operate their systems closer to the limit requiring more advanced tools providing better system visualisation and closer monitoring. Operating systems closer to their limits can lead to unexpected effects. For example on the 27th September 2002 the heavy South to North flows on the Belgian network, caused by French export in addition to exchanges from Switzerland to Germany, reached a peak of 2600 MW and the Belgian system operator was forced to warn the neighbouring system operators that the opening of the Belgian North border, as a last resort, was imminent – the system operator had the full power and authority to take this action. In the US outage serious questions have been asked regarding the role and authority of the system operators and their actions – or rather inactions – on the 14th August. Also in the situation before the Italian blackout, there were large power flows to Italy, with Switzerland acting as a transit country. At the same time this situation is not new. Italy has been an importing country for many years and liberalisation did not lead to major changes. Still it has become clear that System Operators have to implement further improvements with more advanced tools and more strict procedures. Especially better coordination between System Operators for on-line security assessment is needed. One can argue that the Italian blackout was caused because the Swiss TSO did not assess the urgency of the situation as the consequences of the first outage were in Italy, whereas the Italian TSO did not assess the situation as the first outage was in Switzerland.
- **Impact of regulation** – As has been explained in section incentive-regulation might lead to under-investment and lack of maintenance, if no appropriate quality regulation schemes are implemented. In none of the European blackouts are there indications that this was the case. The UK regulator stated: “Power cuts in London and Birmingham were the result of new equipment failure and were not caused by a lack of investment”. For the USA, however, there are indications of under investment or uncoordinated investment in transmission lines. Partially this can be explained by authorisation problems and the NIMBY effect, however lack of regulation or insufficient regulation, especially for interconnections, certainly also plays a role. Regulators are limited to their own country – or to a state level in the USA – and with electricity systems and flows knowing no borders there is a need for some form of overall regulation.

Lessons for the Russian Federation

Disturbances and also larger blackouts will always occur, as a 100% reliable power system is impossible and even undesirable. Investments for improving reliability can only be justified if the associated costs do not exceed the benefits at the consumers’ side. Still it is important to assess what lessons from the recent blackouts can be drawn for Russia. In that respect, two characteristics of the Russian power system need to be mentioned:

- Centralised structure for system operation – System Operation in Russia is characterised by a strict hierarchical structure with the Central Dispatching Unit at the highest level. The staff are well trained and empowered to take any actions needed to protect the integrity of the system. Such an entity does not exist for the UCTE system or for the different synchronous zones in the USA. The North American Reliability Council for example is an association based on voluntary cooperation. The hierarchical structure in Russia allows for easier harmonisation and better coordination. This is an important aspect as lack of coordination between System Operators in different countries (Italy/Switzerland) or different states (USA) played an important role in the recent blackouts. Russia has the advantage that the network has been planned centrally in a very structured way and has not been subject to isolated decision making. There has always been a clear understanding of the importance of a reliable supply of electricity in a country that suffers in winter from such a harsh climate. However the network was mainly planned and developed in Soviet times and in a number of areas the Russian network is interconnected via the networks of what are now other countries.

! Automatic protection schemes – Automatic protection schemes are widely used in the Russian power systems. These schemes mainly aim to limit the impact of disturbances and to avoid large-scale blackouts and were designed and implemented to cater for the unique characteristics of the system viz large demands, generation deficits, long lings and very high voltages. The consequence is that (restricted) load shedding is more frequently used, whereas in Europe automatic load shedding is mainly only used in the event of large generation shortages by means of underfrequency relays. A consequence of this is that disturbances in Russia will occur more frequently, whereas there is less risk for large-scale blackouts.

The Russian power sector is in the middle of an ambitious reform programme. New entities at the central level (System Operator, ATS as Market Operator and the Federal Network Company) have been created. The first stage of a competitive wholesale market has been implemented and privatisation of generation companies is in preparation. This paper has shown that such developments need to be carefully prepared and implemented in order that the existing level of reliability is not compromised. The following aspects can be mentioned in particular:

! The technological rules need to be implemented as a legally binding document for all market participants and network users.

! If incentive based regulation of network companies is considered for Russia then it needs to be accompanied by appropriate schemes for quality regulation.

! Introduction of competitive markets might lead to under-investment in new generation. Currently Russia has a situation with over-capacity in generation. However, experience in other countries shows that generators will rapidly reduce their overcapacity by decommissioning or mothballing existing capacity. Therefore it is important to carefully monitor correct market functioning.

With the present stage of electricity reform in Russia there is an opportunity, which must not be missed, to ensure that the lessons learned from the experience of other countries are fully absorbed. The many advantages of liberalisation should not be gained by compromising the present high levels of overall system reliability.

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