Gesellschaft für KRISENVORSORGE

Europe on the road to a major disaster

When physics and the laws of nature are disregarded, a rude awakening looms

Herbert Saurugg

Introduction The European electricity supply system is undergoing a radical upheaval. What is essential in terms of climate protection policy is leading to the interconnected system becoming increasingly fragile because the approach which is being adopted is non-systemic. Instead of sound basic knowledge, it is wishful thinking and knee-jerk reactions which are determining the approach, and this could end in the greatest catastrophe since World War II.

We can still turn away from this disastrous route. This would require rapid and decisive political action, but there is no evidence of this at present. A systemic conversion of the European electricity supply system into robust energy cells would have to be initiated immediately to reduce the looming susceptibility to failure. From a technical point of view, this would not be a problem, since the necessary knowledge is available and this conversion could be undertaken while the system is in operation.

The greatest obstacle here is the fact that we have so far successfully taught in terms of large-scale technology, and this would have to be supplemented by complementary complexity and networked thinking and adopted as the maxim. This requires appropriate framework conditions. The current route is pointing more in the opposite direction, however, towards centralization, but this makes it impossible to manage a system which is becoming increasingly complex.

The electricity supply is our most important lifeline, without which our modern society could be destroyed within only a few days. We ought to prevent this from happening.

On January 8, 2021, we experienced the second most serious major disruption so far in the European power supply system (ENTSO-E/RG CE - Regional Group Central Europe). The consequences were very minor compared to the first one on November 4, 2006. On that occasion, around 10 million households in Western Europe had to be disconnected from the grid within 19 seconds to prevent a pan-European blackout. This time, those affected were "only" large commercial customers in France and Italy which had contractually agreed to be disconnected should such an incident occur. The precautionary and communication measures of the 43 European transmission system operators, which have continually been improving the situation since 2006, meant the disruption could be rectified after about one hour. Hardly anybody had expected yet another major disruption. Despite everything, nobody knows whether the security mechanisms which have been designed will also be effective when the next incident takes place. The worst case would be a pan-European electricity, infrastructure and supply outage, a so-called blackout, as is expected by the Austrian Armed Forces, or the author, within the next five years.

In the European interconnected system, the expenditures needed to maintain grid stability have been increasing for many years. The Austrian bottleneck management costs, e.g., the expenditures to avert an imminent blackout, have ballooned from 2 million euro in 2011 to 346 million euro. Instead of 2 interventions, interventions were necessary on 301 days within a few years. Although these expenditures fell slightly in 2019 and 2020, they are still far too high. This is primarily down to the fact that the system does not adjust to the framework conditions, which have changed considerably in the meantime, and also the necessary transition to renewable energy.

Lack of storage systems and buffers

Wind and sun are not always available, and there are sometimes significant deviations between forecast and actual production. In a system where the balance between generation and consumption has to be maintained for 31,536,000 seconds per year, this is an enormous challenge, particularly since there is a lack of system-supporting storage systems and buffers. This situation can only be remedied by large-scale power station interven-

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tions, but this does not represent a permanent solution and incurs high costs. In addition, the susceptibility to failure of the whole system is increasing because it is permanently under stress.

Whereas in Austria around 3,300 GWh of pumped storage capacity is theoretically available, the whole of Germany can muster only around 40 GWh. And there are no plans for expansion which are worth mentioning. With electricity consumption currently at 60 to 80 GW, Germany would not be able to cover even one hour of its own electricity consumption. Quite apart from the fact that this would not be technically feasible because only around 11 GW of bottleneck power is available. In the whole of Europe, storage systems with a turbine capacity of around 47 GW are currently available, two thirds of this with a pumping option to refill the storage reservoirs when surplus electricity is available. This can cover or temporarily store only a fraction of European consumption.

The issue of storage ranges from inherent to seasonal, which requires different technologies. The transition to renewable energy so far has disregarded the fact that conventional power stations have the storage integrated in the primary energy (nuclear fuel rods, gas, coal, oil), thus making it possible to balance the continual changes in consumption. But now we have increasing, and increasingly more difficult to forecast consumption, and volatile electricity generation at the same time. Two things which cannot be reconciled without appropriate storage systems and buffers.

Power-to-X

Power-to-X, especially the use of hydrogen, is deemed to be very promising for seasonal storage. In principle, it sounds very tempting, since an existing infrastructure would already be available - the gas grid. The fact that a number of big challenges remain to be solved is usually not mentioned. Least of all the costs. The announcement of a large wave of financial support triggered a gold rush mood and an avalanche of further announcements. It is to be expected that a gold nugget or two will indeed be found. But people should not really expect that a great breakthrough and widespread implementation will be possible within the next few years. What we do need are solutions that can be implemented rapidly, not only in 10 to 20 years' time. On the other hand, we still know relatively little about the potential side effects of the water vapour which is released in huge amounts as the hydrogen is being reconverted to produce electricity. And even more attention needs to be paid to this aspect with the planned methanation, since we already know the effects here because methane is significantly more harmful to the environment than CO_2.

Inconsistency

The general principle is that there is no form of energy which would not have any side effects. Enormous resources are required for wind and PV systems as well, but people usually have a distorted perception of this, unfortunately. The individual system is small and manageable. But if one considers the actual performance and extends these considerations to cover a period of one year, a very different picture emerges. The wrong way of thinking often leads to apples being compared with oranges, or to average values being used. But all that is relevant for the operation is the contribution that one specific type of energy generation can guarantee in order to maintain the necessary permanent balance. This means not calculated as a statistical average over the year, but plannable, reliable and constant. If that were to be done, one would very quickly recognize that it requires much more than simply a production plant.

This is precisely the way of thinking that is necessary to be able to ensure the systemic restructuring of our most important lifeline. Our either/or thinking will not get us anywhere here. We need both/and thinking to master the challenges we are facing. CO_2 emissions can be significantly reduced with renewable energies, but at the same time we also need other elements in the system to be able to continue to guarantee the very high security of supply to which we have hitherto been accustomed.

Instantaneous reserve

Another technical detail which is hardly ever considered concerns the instantaneous reserve, e.g., the rotating masses of conventional power stations. When nuclear and coal-fired power plants are shutdown, these reserves are also disconnected from the grid on a grand scale. The gyrating masses of the synchronous generators play a key role for the frequency generation and maintenance, since mechanical energy is thereby continuously converted into electrical energy and vice versa without the need for controlling interventions. A purely physical process. They can also be thought of as large shock absorbers for load shocks, which have so far ensured that the operation of the European interconnected system has been so stable. These shock absorbers are now being removed and not really replaced, which makes the whole system more susceptible to failure. The instantaneous reserve is at the same time also an inherently available energy storage system, which can temporarily buffer any short-term energy surplus. The generated frequency of the alternating current

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therefore also always indicates whether there is a lack of power or a surplus of power in the system overall. IT-independent control interventions can therefore be specifically performed via the frequency, and the system overall kept stable.

Implementation speed

Approaches which utilize large system-supporting storage batteries and corresponding power electronics already exist, and are already being used in Southern Australia, Great Britain and now also in Texas, for example, to reproduce and compensate the instantaneous reserve. It is supplementary, however, and will never be able to replace the complete instantaneous reserve. Here again, a both/and mindset is crucial. In the ENTSO-E RG CE grid, these systems first need to be implemented on a grand scale, however. As is often the case, the sticking point is not the knowledge or the technology, but the implementation. This would have to take place at the same speed as the other measures are being taken.

Germany is going it alone

The biggest problem is that Germany in particular is taking the second step before the first: Conventional power stations are being shut down in large numbers without an equivalent replacement being available. The emphasis so far has been placed on the rapid expansion of wind and PV power stations or providing massive financial support for them. But what is missing here is the indispensable system adjustment, starting with the lack of storage systems and buffers, and continuing with the lack of transmission possibilities, e.g., lines. In addition, the electricity no longer has to be distributed in a one-way system only because those who were previously consumers have now increasingly become producers as well, e.g., so-called prosumers, and therefore there are also load flows in the opposite direction, for which the system and the protective devices were never designed.

In Germany, it is also assumed, at least in the current planning documents, that in the future, electricity can simply be imported from its neighbours when needed. But somebody else might just have a thing or two to say about that. Because: Where is the electricity going to come from when these countries have already been importing electricity from Germany when they have had shortfalls? In addition, conventional power stations are being shutdown everywhere. And the idea that the wind will always be blowing somewhere is a myth which does not withstand scrutiny. Quite apart from the fact that the transmission infrastructure would still be needed, and this was never built for large-scale electricity exchange. The desire for Europe to be a single conductive sheet of copper is under - standable, but bears no resemblance to reality and ignores physical framework conditions.

Decentralized functional units

Moreover, millions of tiny power stations and new actors can no longer be controlled using the centralized structure and logic which has previously been successful. What is required instead is an "orchestration" of this multitude of components and actors which, with the self-organization of a "swarm", will then automatically play their part in ensuring the security of supply by having a view of the situation in the overall system which is accessible to all. This requires it be restructured into so-called robust energy cells, however, since the increasing complexity will not be manageable otherwise. For complex systems cannot be centrally controlled, they require decentralized autonomous units, where demand, storage and generation are balanced locally or regionally if possible, and not as at present, where problems are shifted around across a wide area. Cross-system synergies (electricity, heat, mobility) must be used as well. The issue is therefore a holistic energy supply in cellular structures, which first requires a rethink in many places. Such an approach is not inconsistent with the previous large-scale system, which will still be required as before, since it will not be possible to supply large consumers such as large industrial enterprises or cities in other ways for some time yet. But these decentralized structures and functional units do enable us to enhance the robustness of the overall system bottom-up and while it is in operation, without interruptions. Cellular structures are not as efficient as the large-scale system we have had to date, but this holds true, only as long as there is no major disruption in the form of a blackout. In such a case, all previous gains in efficiency would be destroyed in a single blow and incredible societal damage would be caused. Resilience and robustness require redundancies and reserves and are therefore generally in conflict with the efficiency mindset, which is driven mainly by economic considerations.

No such thing as one-hundred percent security

Moreover, there is simply no such thing as a failure-proof system, as the European transmission system operators stated clearly and unequivocally in their investigative report on the blackout in Turkey: "A large electric power system is the most complex existing man-made machine. Although the common expectation of the public in the economically advanced coun-

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tries is that the electric supply should never be interrupted, there is, unfortunately, no collapse-free power system."

Increasing complexity

We should therefore learn from nature, where all living things are organized in cellular structures. This has obviously been tried and tested and has survived through time. For what is being celebrated as a decentralized transition to renewable energy is currently anything but decentralized. The whole transition to renewable energy to date only works because of the existing centralized system with the requisite storage systems and buffers. The proposed smart grid and flexibilization measures also depend on a comprehensive, centralized IT network and thus on an increasing degree of complexity. Thus, in addition to the risk of cyberattacks, the result is additional, hardly noticed side effects.

Complex systems

Complex systems exhibit a number of unpleasant characteristics which cannot be managed with our linear way of thinking and machine logic which has succeeded so far. As the number of actors and the networking increases, so does the complexity and thus the dynamics, which we can observe on an ongoing basis, of course. We can hardly keep up. At the same time, the forecast ability of the system behaviour worsens because self-amplifying feedback processes are possible, as can currently be seen with the phasing out of coal power: An increasing number of power plant operators want to abandon coal early because their operation is no longer profitable. At the same time, we have more or less run down the overcapacities which used to be available during the past 10 years, which means less and less scope for action remains.

Phase-out of coal and nuclear power

At the beginning of January 2021, those German coal-fired power plants which had strictly speaking been selected for early shutdown had already to go onstream again because the demand could not be covered sufficiently well. If Germany sticks to its plans to phase out coal and nuclear power, which is currently firmly scheduled for the end of 2022, this will already give rise to critical windows in the coming months, where regional shutdowns to protect the system as a whole can no longer be excluded. It is irrelevant here whether it will nevertheless just work out in 99.99 percent of the time. The electricity supply system knows no leeway here. The balance must be safeguarded 100 percent of the time. There is a risk the system will collapse otherwise.

Lack of basic knowledge

It is unfortunately the case that in many fields and among most of the decision-makers, too, there is a lack of the most basic knowledge about the laws of nature, especially the laws of physics, and also a lack of technical know-how to understand the implications of often ill-considered decisions. This situation is now being compounded by the lack of knowledge on how to deal with complex systems, since this is not part of our universal basic education.

Characteristics of complex systems

One further characteristic of complex systems is that small causes can have massive effects, as we are currently experiencing with the coronavirus pandemic. A virus turns the whole world upside down in a matter of weeks. The consequences of decisions are frequently irreversible. A power plant which has been shut down, deconstructed, and decommissioned is lost forever. It is very expensive to maintain and reactivate power plants which have been mothballed.

Non-linearity means that many of our previous methods of risk assessment fail. The delayed consequences are particularly deceptive since people like to ignore them. They include, for example, the 50.2 hertz problem, which arises when a large number of old installations with inverters disconnect from the electricity grid at the same time, leading to a yo-yo effect. This problem is supposed to have been solved, but we do not know whether this is actually the case. What we do know is that it was ignored for far too long. Neither is the effect immediately noticeable with the instantaneous reserve, or when power plants are being shutdown. Things mount up and there comes a point when something happens which is the last straw and can no longer be controlled -small cause, great effect. And there are no easy cause-and-effect relationships which can clearly be made to take the blame. Things have simply built up over a lengthy period of time. The collapse of complex systems is, as has been well investigated, not a fault but a system design characteristic to facilitate a renewal. Economic theory uses the term "creative destruction". The new can often develop only when the old is broken or has been destroyed. If adopted with our most important lifeline, our electricity supply, it would equate to an intention to commit suicide.

Ageing infrastructures

The transition to renewable energy is not the only reason we are facing a time of great upheaval. The bulk of the infrastructure will reach the end of its service life over the next few years. Most power plants are meanwhile

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between 40 and 50 years old. Some are even older. This means that far-reaching changes will have to be introduced in the next few years. But the currently purely economic considerations and the uncertain framework conditions mean this is not worthwhile. Postponing investments is thus a popular move, but one which increases the susceptibility to failure. And when investments are made only when it is worthwhile, it is already too late. This explains why the liberalized electricity market is also contributing to reducing the reserves and redundancies. What may be acceptable in other types of infrastructure could come to a nasty end if used for the vital electricity infrastructure, as is illustrated by the turkey illusion: A turkey which is fed every day by its owner assumes on the basis of its daily positive experience (being fed and looked after) that the owner only has its best interests at heart. It lacks the most important information that this care serves only one purpose: On the day before Thanksgiving, traditionally the day on which the turkeys are slaughtered, it gets a fatal surprise. This metaphor comes into its own with very rare events which have enormous consequences, so-called extreme events ("X-Events") or strategic shocks. In such cases, we like to mistake the absence of proof for the proof of absence.

Extreme weather events

As if this were not enough, we must also expect that extreme weather events will become more common in Europe just as they already are in Australia, California or Texas. This also means we have to expect serious damage to infrastructures and infrastructure outages. The droughts of the last few years in particular have posed an enormous challenge for conventional power plants, which have to draw their cooling water from lakes and rivers. At the same time, falling water levels reduce the capacity of hydroelectric power plants. In the other extreme case, floods or torrential rainfall events cause problems with electricity generation, as happened in June 2020, for example, when a torrential rainfall event knocked out the biggest Polish coal-fired power station and other generating plants at the same time, leading to a critical gap in supply.

Energy cells are also affected in these situations, but the risk of sudden and widespread outages could be significantly reduced here. Cells do not have greater security of supply per se. But they do help to reduce the potential damage, and this is gaining in importance as a result of the problems illustrated. Moreover, we are still creating many even worse dependencies and hence vulnerabilities by developing a structure which increasingly lacks borders.

Lack of predetermined breaking points

The lack of clearly defined, predetermined breaking points makes it much more difficult to re-establish a network. And this is precisely the aspect that is to be extended even more in the next few years. An EU directive requires at least 70 percent of the capacity of the border interconnectors to be open for the cross-border electricity trade by 2025. Something which can boost competition and thus lower prices on the daily level leads on the other hand to a massive vulnerability of the whole system because it means that less and less consideration is given to the physical limits. A possible interruption can spread much faster and much further. These directives are thus clearly at variance with a robust, cellular approach.

Dangerous trade in electricity

The role played by the electricity trade is paid too little attention on the general level as well in respect of the risks to the European interconnected system. In June 2019, German electricity traders brought the system to the verge of collapse after they exploited a loophole in the regulations. Despite receiving a formal warning and the prospect of high penalties which now loom, loopholes still seem to exist. In the first quarter of 2021, there have already been over 60 frequency anomalies, which are probably caused by economically optimized power plant operational planning. In the whole of 2020 there were around 140 anomalies. The problem is: On the hour and regular as clockwork, half to two-thirds of the reserve which has been held back in order to be able to react to unforeseen power plant outages is "consumed". If one or more power plant outages do actually occur during this time, which is more likely with the timetable change, this could rapidly lead to a further escalation. Although people have long been aware of the problem, the regulators do not seem to see the need to prevent this misuse. This can't go on forever.

January 8, 2021

There are also several indications that the two factors, the reduced instantaneous reserve and the excessive electricity trade, could have played a significant role in the major disruption on January 8, 2021, even if this has so far not been mentioned in any publicly available investigation reports.

At 14:04 on January 8, a bus coupling was overloaded in the Ernestinovo (Croatia) transformer substation, which had then correctly shutdown for its own protection. This led to 13 other units in Southeast Europe being overloaded, causing the European interconnected system to be separated into two parts. The result was a massive increase in frequency to 50.6 hertz in Southeast Europe caused by the massive power imbalance, and a drop in frequency to 49.74 hertz in Northwest Europe. In the Southeast there was excess power of 6.3 GW, which was simultaneously not available in the Northwest.

The very steep drop or increase in frequency indicates that too little instantaneous reserve was available, which should have cushioned such a significant change in power. On the other hand, there was an enormous electricity transmission of approx.

6.3 GW towards Spain and France at the same time. There are hence some indications that the transregional electricity trade could also have played a role here, and led to the overload. Another interesting point is that the bus coupling in the Ernestinovo transformer substation had not been classed as systemically important up to that point, and had therefore not been incorporated into the continuous safety calculations. This begs the question of how many such unnoticed breaking points could still exist. The incident on January 8, 2021 should therefore be understood as a warning to be taken very seriously, even though politicians immediately maintained that the electricity supply was secure. Thirty-six countries are all sitting in the same boat, and if it capsizes, they will all go down with it.

After a blackout

Austria is probably one of the first countries which will be in a position to re-establish a working power grid, although this could still take about one day or longer. It will take at least a week before electricity is flowing everywhere again on the European level. But that is not all.

In general, the consequences and restart times after a widespread and sudden outage of the power supply are massively underestimated. Many preparatory measures deal only with the immediate provisions for the power outage, which usually leads to the procurement or extension of an emergency power supply. Albeit it that the outage phase is still the most manageable one. The considerably longer phases (phases 2 and 3) as systems are being restarted will have much more serious and catastrophic consequences in the other infrastructure sectors and during the resynchronization of the supply logistics, and this is something which is completely underestimated in this dimension because we have no experience of it.

It is primarily the very high security of supply in all areas of our life, especially in Central Europe, which will backfire on us: There is a general lack of self-sufficiency measures or fallback solutions. Far too many people and organizations simply rely blindly on the continuous availability. A turkey illusion.

Protracted restart

It is thus to be expected, for example, that after the electricity supply resumes, it will be several more days before telecommunication services, e.g., cell phones, internet, and landlines, are back in operation because serious hardware damage and overloads must be expected. This takes us to week 2 at least if we are lucky, until wide-scale production and goods distribution can start up again. This does not take account of the international intermeshing in the supply logistics. And neither the people nor companies nor countries are prepared for this. There is thus the threat of an inconceivable catastrophe, which could end in the biggest catastrophe after the Second World War.

What can we do?

In the short term, the only thing that will help is to prepare for the event, which means (in a general sense as well): Prevention and security are important, but not enough. There has to be both/and thinking here as well: We also have to be in a position to deal with unexpected events and get a grip on them. This applies at all levels. For example, preventing cyberattacks is enormously important, yet an IT recovery plan is indispensable, even if you always hope it will never be needed. But hope on its own is not enough. The same applies in relation to blackouts. We are currently undertaking the biggest infrastructure transformation of all time - as open-heart surgery and without a safety net. It could turn out to be a fatal evolutionary mistake.

The most important step begins within your own four walls: Be able to be completely self-sufficient for at least two weeks, looking after yourself and your family from your own pro visions and supplies. This means 2 litres of water per person per day. After the outage, you can cook again, but it is not possible to go shopping. So have provisions such as pasta, rice, and tinned food for two weeks. The same applies to important medication, and food for small children and pets. Torches, a battery-powered radio, rubbish bags and other important articles that you might need. In other words, things you would take with you on a 2-week camping holiday.

Very low level of preparedness

Several investigations have shown that around a third of the population could be self-sufficient for a maximum of four days, and a further third for a maximum of seven days. This is the beginning of a vicious circle, because

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when people can no longer provide for themselves to a sufficient degree, they do not come into work to power up the systems again. A vicious spiral is set in motion. This explains why broad-based self-sufficiency in the population is an essential prerequisite for being able to cope with such a scenario. This especially also relates to those organizations and companies which must be able to maintain an emergency service in such an event, including the energy business.

Stand-alone PV systems

And many PV owners are not aware that their PV system will not supply any electricity either during the outage because most systems are line-commutated. Only stand-alone PV systems, e.g., those supplemented with system decoupling, hybrid inverters, and storage devices, can maintain an emergency supply in their own four walls even in the event of an outage. So, power could continue to be provided for lighting, heating, and the refrigerator/freezer (provisions!). This would noticeably lessen the impact of the scenario. From society's point of view, it would be even more effective and more efficient to construct regional energy cells as rapidly as possible, thus ensuring that at least a basic emergency supply in respect of water, wastewater, heat or healthcare services could be maintained, even during an outage. This will not happen, however, because the necessary awareness and the requisite framework conditions are lacking.

Organizational measures

The organizational measures which are necessary can then build on these personal precautionary measures.

This represents the first step towards sensitizing a company's own staff by giving them a nudge to take their own precautions. On the other hand, full consideration is required as to how the necessary communication can be safeguarded in the event of a blackout. In many cases, only offline plans, e.g., prepared arrangements which have to be available in the minds of the staff, will work. Key staff have to know what to do when nobody else can be reached, and how the handover and supply operates when an emergency service has to be maintained. Raising the alarm in the usual way will generally not be possible because most of the telecommunication systems will go down within a few minutes of the power outage. As far as staff availability is concerned, it is primarily their personal circumstances, such as how far they have to travel to their place of work, or other obligations such as family members who need to be looked after, offices they hold in the local crisis management group or emergency response organizations, which need to be considered. Moreover, an assessment must be carried out as to how long the available resources, for example the fuel for emergency generators for emergency operation, will last, since there is little hope of external supplies coming in if appropriate preparatory measures are not taken. This continues right through to restart plans, where consideration must be given as to the conditions which must prevail before it is even possible for regular operation to be resumed again.

Summary

The European electricity supply system is currently going through a time of radical upheaval, where the crux is: "Too many cooks spoil the broth." This situation has arisen because there is no systemic overall coordination and approach. Each member country is transitioning to renewable energy in different directions, and a coordinated approach is difficult to discern. Furthermore, fundamental physical and technical framework conditions are being ignored and replaced with wishful thinking, and it is foreseeable that this can only lead to disaster. After all, the electricity supply system obeys only the laws of physics. We can still turn away from this disastrous route. This would require quick and decisive action, but there is no evidence of this at present.

Autor

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