Introduction
The COVID-19 pandemic which began late 2019, beginning of 2020 brought a new aspect affecting world’s economy. Players of different industries were not used to global catastrophes, but rather geographically circumscribed ones. The measures taken all over the world to slow down the dissemination of the virus, mostly concentrated on social distancing. In some extreme cases quarantine was applied to the population in regions with high contamination indexes. Both national and local health authorities were deeply involved in monitoring the contamination curves as well as applying and continuously adapting control rules for social contact and working environment. The utmost targets were to protect citizens health and slow down the contamination curves. World Health Organization (WHO) data gives a good picture of the COVID-19 contamination evolution in the last months, as shown in Figure 1. For some eastern regions, the contamination curves seem to be under control, but for the Americas this is not yet the case. Europe, after a stabilizing period between mid-April and beginning of June, is presenting a positive decrease in contamination tendency since then. This can lead us to the conclusion that globally speaking we are not yet facing a clear end to the pandemic and looking forward to getting vaccine as soon as possible.

In the power industry, the direct effects of COVID-19 including the consequent social isolation applied as mitigation measure resulted in a reduction of field services in general, specifically maintenance services. In many cases services have been postponed or extended in time to completion. The direct effect of this could be an increased risk of equipment failure. On the other hand, the verified reduction of system load, between 10% and 30% of the load before pandemic, helps to keep service continuity under control. Figures 2, 3 and 4 gives a clear picture of system load behavior as of the beginning of 2020 compared to the same time span of 2019. As a consequence of load reduction, energy prices in general dropped causing, as shown in figure 5 for NYISO, unexpected financial problems for Generation Companies, Energy Traders, TSO’s and Distribution utilities.

Figure 1 - World Health Organization data of COVID contamination for different regions [Source: https://covid19.who.int/]

KEYWORDS
Covid 19 impact, equipment manufacturers, TSO, DSO, System Operators

Impact of Covid-19 to System Operators and Electrical Equipment Manufacturers
Utility Advisory Group A3
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Figure 2 - Daily load drops in Europe in the beginning of pandemics [1]

Figure 3 - Daily load drops in USA in during the pandemics [Source: https://www.eia.gov/realtime_grid/?src=data#summary/demand?end=20200423&start=20200416]

Figure 4 - Brazilian total load in relation to the previous year load [Source: https://public.tableau.com/profile/ceee.inforne.es.ao.mercado#!/vizhome/ConsumodeenergiaoSIN/AnlisedeconsumonoSIN]

Figure 5 - Drop of US spot prices in the initial phase of pandemics [1]
Having this unusual scenario in mind CIGRE Study Committee A3 – Transmission & Distribution Equipment collected information worldwide from relevant sources, compiled and distributed a questionnaire dedicated to transmission and distribution utilities, as well as HV equipment manufacturers to investigate the effects of the COVID-19 pandemic on their daily business and measures taken to overcome the problems faced. The compilation of the collected information together with the experience of the authors on going along with the effects of pandemics on their working life are compiled and presented in this paper.

The crisis raised several unique challenges. To analyze the real effects of COVID-19 on the electricity sector, it is necessary to verify the measures taken in each country, because the impact is very different depending on the actions taken by individual government entities. The following paper presents a consolidation of the impact on the global electricity sector and the measures taken by Utilities and system operators during the pandemic.

2. Measures for personnel protection, safety and welfare

In all global industries, personnel and personal safety is the highest priority, which gets even more underlined under working conditions during pandemic times. Many companies and institutions whose activities are mainly organized as teamwork in offices or meeting rooms have allowed their employees to work from home, a practice known as home office. Such practice, as a precaution is put in place in order to protect the employees themselves, as well as their relatives. Further, it positively reduces the operational costs of the companies. However, the success of home office replacing the team-spirit in face-to-face activities must still be addressed, in order to keep the high efficiency and reach the company goals. These home office effects are for instance:

- Combine professional and domestic activities at home, mainly when looking after children;
- Home office allows parallel appointments at the same time, both professional and domestic but may on the other hand affect the focus on all these;
- Need for an efficient and secure network connection. Necessary IT systems and its security are put in place, such as secure VPN connection, disk encryption, use of RDP, controlling the use of external devices (e.g. USB storage and peripheral devices), full control of the connecting devices to all the business platforms and systems or access to sensitive data through cloud solutions.

While in typical companies the internal processes and functions can be ensured remotely or outsourced, Utilities face a unique challenge in comparison to the others. The workforce being critical for the continued operation of the business, and the safe and reliable delivery of electric power becomes a spotlight. Countries around the world are taking steps to support the energy sector and to mitigate the negative effects of the crisis. There are myriad challenges that policy makers, regulators, TSO's and DSO's need to address to ensure energy security.

As an example, a number of security measures have been taken to preserve the corporate environment of the Covid-19 pandemic by a big state utility for bulk power generation and long-distance transmission in Brazil. The actions aim to preserve the health and well-being of employees, as well as the company’s operational capacity. The company has adopted more than 30 contingency measures that have been shown to be effective in its offices and in the areas of operation of plant and substations, in addition to the works in progress, including:

- Acquisition of cleaning alcohol, gloves, masks and spray, material that is being distributed to the areas of operation; a number of washable /re-usable masks were provided to every staff member
- Currently, 81% of employees work in home office, while 19% work at the company’s facilities;
- Employees who work in a remote work regime should not be absent from the locations where they work, as they may be extremely necessary on location;
- Employees who perform in person, in the company’s facilities, activities considered essential, such as operation and maintenance of the electrical system, cleaning, work safety and health and implementation of projects with works in progress are not included in the remote work modality;
- All Operation Centers and the Telecommunications Supervision Center have functional redundancy structures. This allows the activities carried out by one center to be carried out by another in case of
contamination by coronavirus from any member of the team;
• Limit national and international travel only to exceptional cases;
• The face-to-face work of external consultants on the company’s premises must be restricted to exceptional situations with limited number of employees in office and ensuring special sitting arrangements;
• Use of antibacterial inserts in the air conditioning system, with cleaning and changing of filters at shorter intervals than regular;
• Rules for usage of lifts, cafeterias, canteens and common areas; and
• Adoption of continuous testing cycles to operators’ teams and providing of 24-hour psychological support.

Following figures gives illustration of the measures put in place.

3. Impact of the restrictions applied to system operators and the supply chain

Maintenance of electrical equipment at generation, transmission and distribution level is generally planned ahead of time. During pandemic, in the majority of cases, the plans are severely limited, and priority is given to the maintenance of critical elements, unplanned outages and ensuring electricity supply to healthcare facilities (e.g. hospitals) and temporary quarantine centres.

Transmission system operators, distribution system operators, generation and supply companies are applying preventative measures to ensure the continuity of supply. The most stringent measures are related to the protection of critical staff (dispatchers and field workers) and control centres across the Energy Community.

As an example, ESB, the Irish utility only allowed their Network Technicians to go directly to site from home, and returning home after any site visit, as well as food and drink for dispatchers in accordance with the special safety measures. Control rooms are being disinfected after every shift, and even special arrangement of shifts including reduced number of dispatchers during shift, keeping reserve shifts in isolation are organized. Further, working methods and processes are adjusted from small written changes or phone handover of the shifts, through partial or total confinement of dispatchers in the control room, isolation of the control room, and even to a possibility of ensuring dispatching from multiple locations, by activation of back-up control centres. In some of the system operators, mobilisation of retired dispatchers and former dispatchers that were reallocated to another position within the company has been activated as a measure to ensure reserve dispatchers.

The introduction of the preventative measures and initiation of corresponding contingency plans result in potential short-term problems. The main ones are listed below.

• Delaying or postponing of scheduled maintenance could lead to network disruption or even possible reduction of NTC (Net Transfer Capacities) at certain times. Where critical maintenance was cancelled, the risk to the equipment subject to the delay increases as failure could result;

• Utilities, system operators and the electrical industry in general might experience shortages of critical parts, materials, components and equipment for repair and maintenance of network equipment due to
limited procurement and transport possibilities. This is in particular true if procurement and transport is to be done from abroad or in case the prices of services or equipment soar.

- Home office and remote working arrangements, including third-party access to information and operation technology systems (IT/OT) increases the cyber risk. Most DSO’s and TSO’s have separation of essential OT and IT systems and infrastructure, including corporate and operation communication systems totally apart. These measures are safe barriers to intrusions in essential systems and data base, besides encryption systems and security measures for communication with staff working from home. IT/OT systems staffs needs to remain alert. [2];
- Ensuring electricity import as a result of lack of liquidity of suppliers;
- Technology gap between currently applied dispatching equipment (SCADA) and the skills of retired or former staff, even re-recruited;
- Decrease of electricity bill collection rate; and
- Meter reading limitations and delays where a remote meter reading is not possible.

In global context, manufacturing activities have been significantly impacted. This affected access to a variety of products, from personal protective equipment (PPE), to components for traditional power plants, renewable generation parks as well as high voltage substation equipment and associated protection & control systems.

Supply chain problems are influencing the schedule of ongoing projects or short-term intervention plans, as identified by the inquire carried out by CIGRE SC A3, whose compilation is presented in item 6 of this document. Wind Europe reported in the beginning of second quarter 2020 the closing of 18 wind turbine manufacturing sites in Spain and Italy [2].

Though supply chain issues have already emerged to a certain extent, the industry as a whole has overcome these. Most utilities and system operators surveyed in April 2020 stated that, delays in supply chain have not been a significant issue so far. This is the result of identifying manufacturers as providing essential services, so the equipment production delays are under control. ESB, issued a daily spreadsheet of suppliers affected by Covid-19 and which factories were closed or on limited production - mostly mainland Europe, and expected re-opening dates. The major concern remains therefore mid-to long-term uncertainties. Supply chains could also see constraints due to border closure and travel bans during any future regional pandemic lockdowns. Shortages may further be caused by disruptions along the supply chain, from transportation to warehousing.
4. Impact to external qualification testing

Development of new products comes along with a variety of power tests. Prototypes are tested during the development phase. Verification of the final design is done by performing type tests before the product is launched on the market. Tests are done in accordance with international standards to ensure that high-voltage products fulfill all duties for a reliable application in power transmission and distribution.

There is a limited number of test laboratories that are capable to perform all tests as required by the standards and for the execution test, objects need to be shipped to the laboratory. Development engineers and testing experts from the manufacturer typically travel to the laboratories to prepare test setup, execute and supervise the test process or attend the visual inspection after test execution together with experts from the laboratories.

Covid-19 has made this protocol quite challenging due to travel restrictions, local regulations or social distancing rules. In order to continue with development and testing activities, while ensuring personal safety some labs have established remote testing programs. This new testing solution enables business continuity and collaboration between the high-power laboratories and the manufacturer, without compromising on quality.

In a nutshell, “remote testing” means shipping the test-object to the testing laboratory while the experts from the manufacturer stay at home and are given the opportunity, through IT systems, to witness, support and evaluate the tests remotely.

Each round of tests consists of three main phases: test preparation, test execution and test evaluation. Test preparation comprises all activities from manufacturing of the test device, shipment of the material to the test laboratory, assembly of the test device at the lab by experts from the manufacturer and the test set-up in the test cell done by the lab experts. Test execution is the most important part of the test process. Typically, this phase is executed while experts from manufacturer and laboratories are in close collaboration, all being present in the control room. After disassembly, done by the manufacturer and supervised by the lab, the visual inspection is in the responsibility of the lab again.

In the case of KEMA Laboratories, the basic structure of the enabling IT approach is outlined in figure 10.

A two-stage connection is used to guarantee a secure connection and to prevent unauthorized login to sensitive information. For security reasons, connection and data transfer is made one way only, i.e. from the KEMA network to an external computer.

In the following, two examples of remote testing performed by KEMA lab in Arnhem, Netherlands are demonstrated. The first is the successful type test of an ABB Power Grids high-voltage circuit breaker with experts online connected from Switzerland. The second one is the research testing of a G&W medium-voltage breaker, with experts connected from USA.

High-voltage circuit breaker remote testing

The breaker to be tested was assembled by the manufacturer and shipped to the lab. A new challenge for the lab was to do the final assembly such as mounting of bushings and terminals for preparing the connection to the test circuit. As this is not a standard procedure but a procedure only needed for testing and mainly known to the manufacturer, the assembly process needed to be coordinated remotely. Live video was used for work directions and supervision.
During test execution phase a close collaboration between manufacturer and lab is essential: to review and agree on the test plan, inspect the test circuit and test parameters. Communication between the lab engineer and expert from manufacturer can be done by conferencing tools which are well known from online conferencing. Additionally, videos, including slow-motion, from the remote-controlled observation cameras are shared online, see figure 11.

Once the testing starts, the remote engineers need to have immediate access to the measured data. Remote desktop applications or sharing data on a common drive are two ways to realize this. With remote desktop applications the client controls the remote computer from his local computer (figure 12). This is an easy way to use any program that is installed at the laboratory’s computer. While the advantage is to avoid installation of new software on the client’s computer the response time on users’ actions (e.g. mouse control) is limited. The transfer of the measured data to a common drive is an alternative. This enables a direct access to the measured data. The evaluation of the data on a locally installed viewer is much faster and more user friendly.

Beside a successful power test, the visual inspection is an integral part of most of the type tests. The sealed breaker is sent back to the manufacturer. In virtual presence of the lab inspector the seal is broken at the manufacturer’s site, the parts are identified, and key parts are sent back to the lab for detailed inspection.

**Medium-voltage circuit breaker remote testing**

For testing of MV switchgear the procedure is basically similar, see figure 13, though the assembly may be less complicated because of the smaller size of the objects.

Upon completion of the type test, visual inspection typically needs to be performed. This can be done in the power laboratory, when the inspector is using ‘Hololens’ or some similar tool and the remote engineer is following (and commenting) on the computer live stream (figure 14).
Alternatively, the sealed breaker can be sent back to the manufacturer and in a virtual presence of the lab inspector the seal can be broken at the manufacturer’s site, parts identified, and core parts are sent back to the lab for detailed inspection.

5. Impact to Factory Tests

Product qualification tests are partially carried out in manufacturers’ internal laboratories. Such type tests include e.g. high voltage impulse testing, temperature rise and mechanical performance tests. Manufacturers’ internal laboratories are accredited for their competency of testing acc. to ISO/IEC 17025 or other International or National standards. The aim of such accreditation is among others to guarantee a laboratory impartiality for performing type tests of own products. This is generally ensured by a third-party observer, being a representative of the certification authority. The observer is normally physically present during the test, supervising and validating test setup, methodology, results and checking of product after the test. All this needs to be in line with the relevant IEC/IEEE standard requirements.

During pandemic time, observers could not enter the manufacturer’s site. Therefore, solutions based on remote observation were put in place. This way of work is already established practice in LV testing. However, it is not pronounced in MV and HV business, also due to different product architectures and processes. The remote observation was arranged using multiple static cameras, continuously monitoring product test setup itself as well as test operator control panel. In case of detailed clarification, other devices were used including smart phones with live communication through social media. This all was generally organized in a short term
and partially in an improvised manner. It stressed the observer in terms of concentration to retain a complete overview of running test. Indeed, to be effective, it was necessary that the observer knew the test premises, internal procedures as well as the laboratory staff.

As discussed in previous chapters, system operators were focused on servicing of life-sustaining critical infrastructures. During shutdown periods, network utilities and operators performed preventative maintenance of their equipment. As business travels have been reduced, Utilities and partners more frequently utilized manufacturers’ webinars and online training to stay connected digitally. Manufacturers service teams carried out emergency repairs, maintenance and upgrades, together with remote assessments utilizing digital assets. In specific cases manufacturer experts gave remote support to local specialists in execution of tests on equipment, such as high voltage condition checking.

Another point is linked with product inspection and final quality assurance through users. Such activity is normally realized through live testing of equipment in manufacturers’ production site. During pandemic time with site access restriction, here remote solutions for factory acceptance tests were also implemented.

As an example, G&W Electric Company leveraged corresponding technology and teamwork to meet customer demand for witnessed testing, while still practicing social distancing guidelines. In the initial stages of the outbreak, G&W Electric Company’s Order Management group teamed up with its Marketing department to produce a short film that documented each of the routine tests associated with the customer’s SF6 switchgear. This included the high voltage one minute withstand test, circuit resistance test, visual inspection, and the full script of relay test steps needed to prove the automation associated with the switch. The presentation included full narration of the required steps, as well as graphics highlighting key items associated with the testing. Social distancing was easily practiced as only 3 people were required to complete the entire production. A factory acceptance test such as this generally requires that the customer be on-site for at least a full day due to down time needed for test setup and movement of equipment. The completed film consolidated all activities and allowed the customer to witness each of
the required tests in approximately 1 hour with no travel requirement.

In the weeks following, G&W Electric Company began to employ virtual meeting technology such as Zoom and Go-to-meeting to provide a more interactive experience for customer witnessed testing. Large groups from multiple locations were able to enter virtual meeting rooms while G&W team members broadcast real time activities from their computer screen. Same principles as described above were used. HD video camera mounted on a tripod was used to capture the overall equipment setup, while handheld smart phones or tablets were used to provide live close-up feeds of the equipment.

To date, G&W has successfully completed live virtual customer inspections of operation life testing and impulse BIL testing, in addition to validation testing of complex networks of integrated switchgear related to the distribution automation projects.

Virtual testing has proven a valuable tool for meeting customer demand, and it is something that G&W Electric Company will likely continue to offer for the future applications.

Insights to remote factory acceptance test (FAT) procedures are given in figures 15 and 16.

6. Financial impact on system operators & manufacturers

As a consequence of the COVID-19 pandemic, the USA’s total industrial production rose 5.4 % in June 2020 after increasing by 1.4 % in May. In spite of that, it remained 10.9 % below its pre-pandemic February level. For the second quarter as a whole, the index fell 42.6 % annually, its largest quarterly decrease since the industrial sector retrenchment after World War II, as reported by FED [3].

A brief resume of the PwC analysis on the financial impact on the power industry due to the COVID19 crisis is following presented [4].

With economies of scale being forced to shut down businesses and people being retrenched, the potential for a global recession increased. Unemployment reached an all-time high throughout the world. Businesses were forced to close to reduce the risk of the virus spreading and many companies could not sustain a prolonged shutdown resulting in permanent closures. Governments were forced to borrow money to support the unemployed and the people affected by the virus, with a massive unplanned increase in spending on medical equipment. This all increased the strain on governments increasing the risk of recession.

**The effect on the workforce/reduction in productivity.**

The positive effect of COVID-19 was a definite increase in worker productivity - when working from home, where disruptions were limited and staff were not required to be traffic bound for up to 4 hours a day, time spent productively on work. But with factories being shut down during this period in many countries, due to the risk to staff, output was reduced from limited production to cases of no output. This was prevalent in countries like Spain and Italy where the virus caused massive infections. As factories could not produce critical components or equipment, this put a further strain on economies and increased the risk on critical sectors.

**Decrease in consumer confidence reducing consumption.**

Due to a lack of understanding of the virus and its effect people initially started panic buying and as infection figures increased, confidence started dropping and consumer confidence dropped, resulting in a massive reduction in consumption.

**Supply chain disruptions.**

Due to the severe effect of Covid-19 on manufacturers, many factories were forced to close by the respective governments and production totally ceased. With no spares being delivered, this resulted in downtime in limited cases having a definite financial impact. Examples are factories shutting down or with output totally stopped. In certain cases, these factories were providing critical components to utilities, and as such increased the risk of critical failures should a breakdown occur.

**New build substations.**

Especially in cases where capital is already committed for projects, and projects subject to completion of associated projects, the capital was assigned but could not be utilized and manufacturers had to pay interest on capital they were not getting, due to delays. As people were still not sure on the various effects of the virus and its transmission, the employers could not risk sending people out to carry on working on new build substations. The capital in this case were...
An example on Brazilian economy shows the financial impact, which are illustrative in global scale with main boundaries being [5]:

- The slowdown in the economy will strongly impact electricity consumption, which could fall 4.7% in a scenario considered “optimistic”. In a “moderate” view, the decline in demand could be 7.9%, while a “pessimistic” scenario could lead to a 12.3% drop in electricity use.
- The projections take into account a 3.6% decline in Brazilian GDP (Gross Domestic Product) in the optimistic scenario and a 6.1% decrease in the moderate scenario, while the pessimistic view would involve a 9.5% decline in the economy;
- The expectation of market analysts for the performance of the Brazilian economy this year is a fall of 5.89%.
- Energy traders expect a negative impact of R$ 5 billion this year due to these requests for flexibility and the lower consumption by their customers as a result of the coronavirus.

It should be pointed out that the reduction in consumption has been more expressive in the free electricity market, in which large customers such as industries negotiate their supply directly with Generation Companies and traders, which will be accompanied by renegotiation of contracts and even a possible increase in default in this sector, as shown in Figure 17.

**Difficulties with funding.** Due to uncertainty as to the length and severity of the lockdown, funding was more difficult to obtain based on possible downgrading of credit ratings of utilities / countries. Countries like South Africa already having a very bad credit rating, now faced the situation of further reduction in credit ratings resulting in greater unemployment, higher interest rates.

**Not having enough information** to make good decisions. In many cases the people of the country does not understand the effect of the virus, seeing it is a scare generated by the government and due to this lack of understanding, wrong or poor decisions were made where more people were put at risk increasing the cycle of infection and putting further strain on health care systems.

**Impact on tax,** trade, or immigration. Many technical specialists’ applications were put on hold and most EU countries totally stopped immigration and influx of any people. This also affected the power industry where many specialists are based on mainland Europe and could not travel to sites where critical maintenance are required.

**Cybersecurity risks** – financial scammers and Cyber terrorists grabbed the opportunity to release emails to cause havoc with IT systems and ransomware to damage IT systems with the COVID-19 subject in all emails. And so, catching the eye of the recipient to open the email.

**Fraud risks** - as companies were suddenly forced to let large amount of people work remotely, not all requirements were put in place in advance to ensure security and as such many people were connected to open networks resulting in data being put at risk. With all this many people’s Privacy were also put at risk as procedures how to deal with remote work were not in place and this opened many doors to fraudsters and Cyber attackers.

Most of Europe adopted some form of lock-down and several countries have already started relaxing rules since June 2020. This impacts directly the country’s economy, what can be measured by the impact on gross domestic growth (GDP). Analysis carried out by...
Statista, a Business Data Platform, on the GDP forecast for several European countries sowed a negative growth for all of them in 2020. For 2021 the GDP forecast shows positive growth, but lower than the 2020 drawback, as shown in Figure 18:

7. Survey results
A survey on the effect of COVID-19 was performed by CIGRE SC A3 for both Utilities and Industry. The full results of the survey are available at CIGRE SC A3 website, https://projeta3.cigre.org/.

7.1 Industry – 5 responses
On the question of any impact on the production line, all companies had to adapt the processes with 40% companies advised of delay in production.

Up to 60% of companies had difficulties, after the pandemic started, in purchasing subcomponents. Logistical problems accounted for up to 60% of issues, 60% of a delay in delivery of spare parts or cancellation of orders. In all this 75% of customers accepted these delays after being informed.

COVID-19 affected all companies (100%) in participation in events or marketing, with all events being cancelled, postponed or moved to a web-based event. Up to 80% of the companies participated in events promoted by external partners.

The financial impact was felt by about 60% of companies already impacted with a further 25% responded that a relatively high risk of still being affected existed.

Companies utilized less than 50% to a maximum of 75% of staff working from home. 60% of companies also provided medical support to staff with 80% of companies providing psychological support.

7.2 Utilities – 15 responses
On the question of whether practices were changed or postponed, or changes made, more than 45% of utilities made changes. Mostly maintenance was postponed, or a risk analysis performed before postponing or cancelling work.

More than 66% of construction slowed down or delays in work were applied. With respect to grid reinforcements more than 50% were late with utilities cancelling some. The biggest impact in this case was maintenance and erection of new installations and a limited effect on implementation of reinforcements. Up to 53% of replacement work were late due to the effect of COVID-19. Utilities reported 46 to 53% of issues in supply chain problems for new equipment and spares.

60% of utilities reported definite financial impact due to the pandemic with up to 65% reporting a relatively high risk of future financial impact.

Most utilities responded that 50 to 75% of the workforce utilized the ‘home office’ where facilities were in place. Utilities responded with a 56% rate of medical and psychological support for employees.

8. Conclusion
The global electric markets were impacted by the Covid-19 crisis. Due to the relevant measures of social distancing and the consequent reduction of economic
activity, demand for electricity has drastically decreased in several countries. Despite differences in physical and regulatory aspects of the power sector between countries, it was possible to clearly notice a change in the load behavior and consequently in electricity spot prices caused by common factors [6].

No COVID-19 network congestion issues or problem with security of supply have been reported in Europe’s systems. The EU regulatory framework of liberalised energy markets regulated by independent regulators working for an integrated internal energy market has shown its resilience. System operators and utilities have activated necessary plans to ensure reliable and safe electricity supply, especially to centers of strategic importance. It was further supported by collaboration of their representatives, who have been exchanging experiences and ideas through more frequent phone calls and e-mails. Under the restrictions on movement and following home-office guidelines, the amount of power utilization by businesses was declining, while residential consumption was rising. The electricity and gas demand have fallen significantly in recent weeks, by as much as 15% or more in some countries. Many regions were experiencing daily load levels comparable to those on weekends. This, combined with commensurate wholesale price declines and later consumer bill payments, has put some Generation Companies and/or retailers under pressure. Where suppliers are facing stark temporary difficulties, where appropriate, regulators have taken actions with their governments such as providing insurance and bill rescheduling, [2].

It is important to keep in mind that a hazard like COVID-19 does not develop to a disaster if the appropriate measures are in place and rapidly activated. However, this is only possible through effective multi-discipline management and strategic planning over the years to predict and effectively manage the impact of disruptive incidents to the continuity of mission critical operations. This requires risk-averse or risk informed decision-making and proactive rather than reactive thinking to develop holistic resilience enhancement frameworks, which would proactively enhance the infrastructure, operational and organisational resilience to be able to withstand and rapidly recover form large-scale, disruptive incidents.

Safety measures have been instituted to safeguard utility employees, contractors, and the public at all times from infections. Electricity utility’s contribution to the COVID-19 fight is to sustain electricity provision, especially to critical and essential sites, and to residents under the national lockdown period. When returning back to workplace, utilities must have COVID-19 risk assessments and plans in place and must conduct worker education on COVID-19 protection measures. These safety measures must be monitored to ensure that compliance and effectiveness with the safety protocols and identification of new infections among employees.

In summary, system operators, energy companies and equipment manufacturers mobilized their capabilities and resources to maintain critical infrastructure and business continuity during the Covid-19 pandemic. Priority remained the health and safety of the employees, users and partners. In coordination with local authorities, working principles were deployed, which included: Coordination with users before site visits and service interventions through possible remote access, Controlled access to manufacturers sites aligning to social distancing, Clear information on safety, sanitation and disinfection measures, Utilization of personal protection equipment and alternate working solutions using digital tools.

Figure 19 – Survey question
From the results of the survey it can be clearly seen that the impact of COVID-19 affected all industry with the biggest change in production line processes, logistics and financial. The way that products and services were provided all changed with a greater use of technology and web services for both marketing and product support. For utilities, the greatest impact was on delay or postponing of work and maintenance as well as on the way staff were doing their work. It meant many procedures and processes had to change but again technology eased the way things were done with specialist being available by phone. Supply chain caused issues in new builds or getting spares and equipment.

The COVID-19 impact is felt and will be felt for a long time as the impact for both utilities and industry are financial in all cases and by planning for the future is the only way to soften any future impact.

What is next?

Covid-19 pandemic has given direct evidence of appropriate protection methods used by system operators. It can be envisaged that all system operators will come out strengthened. Since society and business will adapt to the changed working environment, further improvement, additional emergency plans or specific methods of system control and maintenance still needs to be prepared.

Although Generation Companies will already have largely hedged generation levels for 2020, the current uncertainty will lead to a high demand for hedging transactions to sell power output in advance for 2021 to traders, industrials and retail suppliers. Investment decisions in wholesale power market exposed wind and solar projects might see delays awaiting an uptake in forward power markets and a reduction of market volatility.

Manufacturers utilized remote testing for qualification of electrical equipment and FAT. In general, remote testing offers a set of advantages and enables business continuity even in difficult times. It enables flexibility like involving experts from remote places or on short notice. It can increase efficiency and reduce time by avoiding traveling around the world. Digitalization, remote assistant and online video tools become part of a new way for testing. Beside those tools, we should not forget that trust and mutual understanding is the key to make remote testing successful and that trust and mutual understanding needs face to face meetings at least to a certain degree. Although the digital world might not be able to completely replace a face-to-face cooperation in the lab, it offers new opportunities such as high flexibility or faster response time or involvement of more specialists. As the remote assistant system is set up and is active during testing, experts from anywhere can be easily involved at short notice into the test process on demand. Test engineers can easily assist power testing the next day in a power lab at another location without traveling a long distance. As a further and future development, the use of Mixed Reality tools such as ‘Hololens’, might be expanded to Augmented/Virtual Reality (AR/VR) applications. This enables the use of digital twin technology to directly link the real test-object, subjected to real stresses in the test-laboratory to a model in the manufacturer’s digital design platform. This will lead to development of “virtual testing”, as an addition to physical testing. AR applications are already in pilot use in the industry, mainly for maintenance of substations. For laboratories, having multiple locations in the world, systems are in development to remotely supervise, control and manage testing in satellite labs from a master laboratory. In this way, the limitations enforced by the COVID-19 situation accelerate the “remote testing” technology, at the same time increasing efficiency and reducing costs.

The crisis highlighted some supply chain issues, however clear communication between partners in Energy sector was put in place in order to find acceptable solutions. In some cases, manufacturing lines were temporarily changed to build ventilators, parts of automation systems and medical protection equipment, e.g. face masks and shields. Here the collaboration between several technology and industry partners was key.

From the results of the survey it can be clearly seen that the impact of COVID-19 affected all industry with the biggest change in production line processes, logistics and financial. The way that products and services were provided all changed with a greater use of technology and web services for both marketing and product support. For utilities, the greatest impact was on delay or postponing of work and maintenance as well as on the way staff were doing their work. It meant many procedures and processes had to change but again technology eased the way things were done with specialist being available by phone. Supply chain caused issues in new builds or getting spares and equipment.

The COVID-19 impact is felt and will be felt for a long time as the impact for both utilities and industry are financial in all cases and by planning for the future is the only way to soften any future impact.

What is next?

Covid-19 pandemic has given direct evidence of appropriate protection methods used by system operators. It can be envisaged that all system operators will come out strengthened. Since society and business will adapt to the changed working environment, further improvement, additional emergency plans or specific methods of system control and maintenance still needs to be prepared.

Although Generation Companies will already have largely hedged generation levels for 2020, the current uncertainty will lead to a high demand for hedging transactions to sell power output in advance for 2021 to traders, industrials and retail suppliers. Investment decisions in wholesale power market exposed wind and solar projects might see delays awaiting an uptake in forward power markets and a reduction of market volatility.

DNV GL has assessed two scenarios to analyse the impact of the Corona crisis on the European wholesale power market, based on exogenous assumptions [7]:

- ‘V-shaped recovery’: Immediate impact on economic activity and electricity demand in 2020, and a relative fast rebound of the global economy by 2021;
A sharing of experiences between the involved stakeholders, represented firstly by governments and regulators, will continue thus ensuring stability during times of crisis. It will also serve a smoother return to normality post-crisis, without interfering in the connected energy system. Long term impact to energy consumers will be safeguarded by a demand regulation approach, extending Europe’s operative energy market, [8].

Following relaxation of lockdown measures, manufacturers are returning to fully operational mode in accordance with their local guidelines and under continuing unusual business conditions. Applied working principles include: Coordination with suppliers and partners to secure alternative sources and shift production on demand basis, Facilitation of downstream transportation lines and Rebalancing impacted global inventories and service parts stock.

Energy companies are launching foundations to help in faster recovery or increase resiliency of infrastructure as well as to provide professional training to vulnerable communities. In total 65 project were supported by Tomorrow Rising Fund of Schneider Electric. Through this activity, emergency support and long-term reconstruction are being fundraised directly through Schneider Electric employees and partners [9].

The European energy sector is implementing the green deal, which aims to make Europe carbon neutral by 2050 and ‘the EU’s economy sustainability’. This will result in accelerating and increasing RES deployment, moving towards cross-sector optimization and electrification, among others.

The true impact of Covid-19 is still to be determined, however some plans for post-COVID-19 recovery that promote sustainable growth through the green and digital transition are already created [10].

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10. References


1. Summary
Due to the increasing complexity of electricity networks around the world and the high utilisation of the network, it becomes more and more necessary to be able to determine which generators and loads cause the flow in a particular power line. The Full Line Decomposition method (FLD) developed by TenneT TSO BV is one of several methods that can fully attribute flows to generator-load pairs, based on physics [1, 2, 3]. The FLD method is designed for networks with AC branches and therefore it needs to be complemented with the capability of decomposing the flows in networks with meshed HVDC lines in the same synchronous zone. This paper considers how the FLD method can be adapted in order to handle meshed HVDC lines.

2. Introduction
The FLD method was developed to fully decompose the flows in each line of an AC network model into causing generators and loads, with nodal or zonal granularity.

On a nodal level, the method finds the power that each pair of generators and loads exchange. This exchange is then used to determine the contribution of the pair to the flow of a given AC line. The contribution of Phase Shifter Transformers (PSTs) to the flow of the line is also determined. A PST actively adds cyclic power flows in the network.

If the network is subdivided into multiple zones, the nodal results can be summed up to obtain zonal results. For zones $A$ and $B$, the sum is taken of the contribution of the pairs of generators in $A$ and loads in $B$. Depending on the location of the generator, the load and the line whose flow is being decomposed, the flows are labelled according to the ENTSO-E flow-type definitions [4]:

\[
\begin{array}{ccc}
\text{Source} & \text{Sink} & \text{Line} & \text{Flow Type} \\
A & A & A & \text{Internal Flow} \\
A & B & A or B & \text{Import/Export Flow} \\
A & A & B or C & \text{Loop Flow} \\
A & B & C & \text{Transit Flow} \\
\end{array}
\]

The resulting ENTSO-E flow types per zone can then be used as the basis for a cost-sharing scheme. This FLD is one of the methods being evaluated for flow decomposition to be used for cost-sharing of remedial actions in Central Europe. The cost-sharing principles, to be developed according to the EU 2015 guideline on capacity allocation and congestion management (CACM) art. 74 [5] will define how costs may be shared amongst the TSOs used to solve congestions on cross-border relevant AC lines.

However, in networks with meshed HVDC lines, which are modelled as load-generator pairs, these representing "HVDC" generators and loads will participate in the flow decomposition. Additionally, the decomposition of the flow in the HVDC lines needs to consider the fact that this power flow is controlled to match a specific power setpoint, independently of conditions in the surrounding AC grid.

Each HVDC line acts like two equal and opposite power injections: a load at the rectifier and a generator at the inverter. HVDC lines will transmit active power flow in between the two converter stations.

With the integration of HVDC interconnectors such as COBRA Cable and ALEGro and HVDC links internal to a bidding zone, such as StedOstLink in the continental European System, the capabilities of the