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Rapid urbanization is on the rise. How does this impact civil project design in dense urban settings?

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SUMMARY

Due to the continued population increase and the move to decarbonize energy consumption in urban areas, there is an over-proportional demand increase for electric energy. To adequately support this growth, new civic industrial projects arise every year which contribute to develop electrical systems that can operate closer to where the demand is – in Urban Centers.

Citizens should directly benefit from the project once it is completed and delivered to the local community. These benefits, such as new and improved infrastructure (school, parks, community centres) combined with a safe-to-operate and maintain station, must be strategized, quantified and elaborated upon in order to achieve acceptance and success of the project.

The ultimate goal is that these projects must have a real and perceived positive impact, instead of just minimizing the disturbance to the area. It requires a significant effort, together with solving technical challenges to build in-city projects. By working together with the community, we must make sure challenges and benefits are understood through transparent and honest political and social engagement. In addition, community and environmental, health and safety concerns must be addressed through each stage of the proposed project from planning, to construction, to long-term operations including:

- Noise, dust and other impact from construction, operations, maintenance
- Risk mitigation of uncontrolled release of energy, liquid, or gas, to the environment and community
- Use and disposal of hazardous materials

The intention of this paper is to present and explain the social and technical nuances of successfully installing a technical power infrastructure solution within the context of a modern urban community. We will consider the social interface as well as the state-of-the-art equipment, systems and proven technical solutions that are available, and which should be embraced for the benefit of the community and the environment.

KEYWORDS

Underground substation, Urban infrastructure, Plug & Play Transformer, Resilience, Environmentally friendly, High Temperature Insulation System, Synthetic Ester, Asset Management, Clean Air Insulation, SF_6-free, F-gas free, Zero Global Warming Potential, Carbon Neutral, non-toxic, Asset Management, Sustainability.

1. Introduction

The Basic Science of electrical generation was developed in the 1830's, the hardware for its distribution in the 1880's and its deployment across Europe and North America was well under way by 1930. By the 1950's and 60's much of the technical infrastructure we see today was deployed, "over-engineering" the equipment at the time in anticipation of population growth. Since then, the growth anticipated has been vastly exceeded (1950=2.5 billion people, 2020=7.8), the 50-year lifespan of the equipment has been eclipsed, and the power demand has reached unprecedented levels with the aid of a cornucopia of new devices from cell phones to electric cars paired with a drive to decarbonize the energy value chain. Furthermore, the movement of our population from rural to urban centres, measured as 64% urban in 1950, 83% today and 89% projected by 2050, has concentrated that demand in specific locations. [see also reference section for further information]

The result is that we find ourselves, working together as diverse professionals, including engineers, architects, equipment manufacturers, community planners, educators, etc., seeking creative ways to meet the technical demands for power for an evolving population while also addressing the politics, the social concerns, and other needs of long established urban communities, rightly focussed on preserving and improving their collective quality of life, while sustaining their ecological context. Faraday, Edison, Yablochkov, Crompton, early innovators in this space from around the globe, would hardly recognize the place, or appreciate the profound impact of their work, on it. Picking up their heavy mantle, our opportunity is to have as dramatic an impact, focussed on the long-term sustainability, refinement, upgrades, and optimization of electrical power and distribution systems as we plan and locate state of the art equipment and technical facilities within our densifying communities.

2. Community benefits

Just as with the advent of arc and then filament light in public space a century and a half ago, the continued and enhanced provision of electrical service has long term community and individual benefit. Continuity of electric power in public space enhances public safety in the form of lighting at night, as well as traffic signals, and electric transport in the form of trains and busses, and more recently also individual vehicular traffic. Community, business, and industrial functions rely on power at workplaces, community facilities, health care, education, etc. Personal safety and convenience are enhanced by lighting, refrigeration, security systems, data and communications technology, equipment power points, vehicle charging etc. Many power applications have become so critical that un-interrupted supplies have been devised, as well as alternate and mobile power sources to serve in emergencies or maintain critical infrastructure or life support.

Power has become over time extremely important in a community, but what has interestingly evolved alongside these 150 years of development, is that power has become an expectation. It is perceived to be a gift without reciprocal obligation, like the rising of the sun or the timely arrival of the seasons. As technology-solutions providers we are bemused on occasion as we encounter this perception when individuals or community groups are presented with the concept that power, like other infrastructure must logically be upgraded from time to time. And there will be cost, spatial needs, construction periods, and perhaps power interruptions associated with that infrastructure enhancement. And so, as we set out to advance these upgrades, we open a conversation with an extensive array of stakeholders, who, as we articulate the needs for technical solutions, they articulate the evolving wider needs of their community, and their concerns for the health, education, and safety of themselves and their children, and their need to understand the long-term consequences for their community and for the environment.

We find ourselves engaged in wide-ranging conversation in the community, on diverse subjects, in the interest of discovering common ground as to what has and has not been successful in the past, including righting of consequences brought on by previous strategies. We discover that preconceptions with respect to technical infrastructure were understandably acquired because when infrastructure is working it is ubiquitously silent and when it fails, it has, on occasion, been dramatic. And we discover that just as infrastructure enhancement has tangible and physical consequences, the meeting of community needs must also be tangible, in the form of, for example, better technical features than in the past, greater performance efficiencies and enhanced environmental characteristics. We also are compelled to come alongside the community, to think holistically, for example examining the economic model which supports the provision of the technical asset as a model which might be harnessed and leveraged to supply additional infrastructure that specifically supports a social need for example, a health, education or community facility.

Through engagement with local government and the community we arrive at common ground with respect to infrastructure development. In order for these projects to be permitted and ultimately successful we expand our perspective beyond simply the supply of a technical solution to a current problem. We actually are supplying a long-term community asset, often a suite of assets, which must be aligned with the long-term needs and future aspirations of local residents. In that wider project awareness, we understand that for each stakeholder, these projects must make a real and a perceived positive impact today and well into the future, instead of just minimizing the negative consequences of technical development to the area. In addition, community and environmental safety concerns must be addressed relative to each stage of the proposed project from planning, to construction, to long term operations. Safety and nuisance concerns expressed by stakeholders could include:

- Loss or compromise of available land for public / community use
- Noise, dust, road closure, safety from construction, operations, maintenance
- Increased traffic due to service vehicles
    - Regular service intervals,
    - Periodic major service events,
- Uncontrolled release of energy, liquid, or gas, to the environment / community
    - Heat output, cooling, noise, etc.
- Ecological Sustainability concerns:
    - Use and disposal of hazardous materials
    - Environmental consequences of servicing, and eventual demobilization / decommissioning
- Fear of Catastrophic failure(s)
    - Environmental consequences of catastrophic events such as earthquakes or on-site fire

The community is savvy towards change and have access to multiple sources of information. It requires a significant understanding and effort, together with a thorough and detailed grasp of the technical challenges to build “in-city” projects. Working together, we make sure challenges and benefits are understood, and we make strategic use of the main communication channel: transparent and honest political and social engagement.

2.1. New features / better infrastructure

New infrastructure/transformers with low noise technology

In every power supply network, transformers are strategic interconnecting nodes. With current efforts to decarbonize the energy supply chain, electrification of power delivery (e.g., e-mobility) experiences a tremendous upswing. This results in power transformers that become larger and, in many locations, acoustic environmental protection for transformers has now, more than ever, become crucially important. Limited space in cities and strict noise-control regulations require extra efforts when building electrical equipment such as power transformers. Siemens Energy, as a leader in power transformers, has answered this challenge by developing specialty solutions and for over half a century have achieved and demonstrated significant results in reducing transformer noise emission for urban applications.

2.2. Energy recovery technologies

Often, there are secondary characteristics of an infrastructure project which must be mitigated. Several of those of concern to communities are identified above and become active conversation topics with local government and community groups. Equally often, a project presents an opportunity to benefit the community through the harnessing of a project’s secondary characteristics. The capture, conditioning and distribution of excess heat produced by, for example a power substation can be such a community benefit.

A community power substation produces heat in excess of its requirements for normal equipment and facility operations, even in its most energy efficient form. Depending on the size of the equipment, the facility and the nature of enclosure inherent in the facility configuration, the heat, at least at peak demand can be substantial. Within an urban context, this heat might be sufficient at times to satisfy the winter needs of an office or apartment block, or a community facility, a school, or an aquatics centre.

The common way of dealing with excess heat is to either directly or through heat exchange equipment, dispense with the heat through ducting to the surrounding air. The advantage of this solution is that disposal can be matched exactly to generation and it involves very simple equipment, largely in the form of fans. Disadvantages are the obvious loss of heat to the environment, which is a missed opportunity during cold seasons, it typically employs venting towers, which can be obtrusive for an otherwise below-grade project, for example, and it tends to add an often unacceptable fan noise level to its context.

Several projects in the conceptual stages at the moment are considering heat capture and distribution solutions for urban power infrastructure projects. By virtue of the inherent energy conservation of such strategies they are a positive gesture in terms of ecological sustainability, and they provide a tangible community benefit of cost savings for heating of facilities during cool seasons. A relatively simple technical concept, there are several challenges to be resolved, but with each challenge there are avenues towards implementation that are being explored. Several of these include:

- The challenge of a sufficient temperature delta between the heat produced and the surrounding context can be mitigated, for example, with the use of simple heat-pump technologies.
- The challenge of matching heat production with the load demand can be mitigated by choosing heat recipients with similar use characteristics to the heat production, and by building in complementary and redundant systems on both the demand and the production side to smooth the interface. For example, on the demand side, a public or strata aquatics facility has a relatively constant need for heat to maintain water temperature in its pool. It can absorb heat when available and supplement with traditional methods when necessary. On the supply side, a heat to ground or heat to air redundancy strategy will likely be required by the power infrastructure facility to smooth heat transfer between peaks and valleys and to provide a transfer mechanism when the recipient demand is off-line.
- The conveyance of heat from the source facility to the use opportunity can be a challenge. When adjacent to each other, such as, for example, a community centre or school next to a substation, the transfer can be made using piped water or refrigerant from heat exchangers within the source facility. Real-life examples of solutions that address such challenges have already been proven successful. One of them is the National Grid Highbury 400 kV substation in North London (UK), where Siemens Energy provided a solution in which three 240 MVA transformers supply more than 1MW of environmentally friendly heat that is safely and economically recovered to heat local homes, shops and a nearby school [1].
- At greater distances, more creative solutions can be considered such as putting the heat into the community sewer system at the heat source and extracting it several blocks away at, for example the community aquatics centre.
- Conveyance from one location to another brings up issues to be resolved in terms of property lines to be crossed, operations and maintenance responsibilities to be resolved, demand and supply maximum and minimums to be agreed to and supplemental systems to compensate for load misalignment. Each of these are technically manageable, and through an open communications strategy from the project outset, can be resolved socially / politically.

As these projects evolve, facility and equipment designers need to work with community groups towards the achievement of these energy sharing objectives and need to publish the results so that these strategies can be further refined in projects world-wide by our industry practitioners and partners.

2.3. New schools / parks / community centres

Power, like other infrastructure must be upgraded from time to time. And there will be cost, spatial needs, construction periods, and perhaps power interruptions associated with that infrastructure enhancement. At its simplest, this is a technical challenge, an engineering project with known needs as input and known solutions as output. But, as earlier described, when this project arrives on the doorstep of a community, it becomes clear that in order for it to be permitted and ultimately successful the technical community must expand their perspective beyond simply the supply of a technical solution to a current problem. They actually are supplying a long-term community asset, often a suite of assets, which must be aligned with the long-term technical, social and cultural needs and future aspirations of local residents. In that wider project awareness, the design community must understand that for each community stakeholder, these projects must make a real and a perceived positive impact today and well into the future.

And so, the needs for technical solutions to address present and future infrastructure limits are articulated, stakeholders articulate the evolving needs of their community, and their concerns for the present health, education, and safety of themselves and their children, and their need to understand the long-term consequences of the project with respect to the environment.

In the interest of discovering common ground with stakeholders, the design professionals covering many disciplines describe the technical and physical infrastructure enhancement required to support the community. Through conversation they grow to understand the wider needs of the community and the physical and economic mechanisms available to address those needs. As they come alongside the community a holistic think process begins to emerge. For example, they begin to understand the economic model which supports the provision of the technical asset as a model which might be harnessed and leveraged to supply additional infrastructure that specifically supports a social need. It is through this thinking that the design community begins to explore means to harness the economic engine which drives the infrastructure improvement as a means to also support for example, a health, education or community facility.

For example, as an urban community develops, it is not uncommon for its population to double or triple in the space of two to three decades. As most of the infrastructure to support this development is focussed on the immediate needs for housing and retail, the additional assets of community and recreation facilities, schools and health centres often lags, leaving an amenities gap in the community that prevents distinct groups such as families or seniors to take up proportional representation. The opportunity of an infrastructure upgrade, when considered holistically, presents a mechanism by which this critical amenity gap might be addressed. A specific example currently under consideration in Canada is the contribution to an established urban community of two schools in order to facilitate the integration of a power transformer and distribution facility integrated into a new park and school in the community.

2.4 Site specific requirements – substations reclassified to be within a flood zone:

According to a report available on the United Nations website, it is estimated that 40% of the world's population lives within 100 kilometres of the coast. According to the National Ocean Service, eight of the ten largest cities in the world are near a coast and impacted by the rise of global sea levels. High voltage substations, which were once built-in areas that were deemed to be a low risk for flooding can find themselves operating in a reclassified flood zone that sees an increasing risk for flood events. Therefore, substation owners / operators are faced with the prospect of seeming like they are gambling each year that passes without a serious flooding incident. Our paper does not discuss what level of risk utilities can accept with operating substations in areas which have been reclassified as having increase flood risks. However, solutions do exist which allow a substation refurbishment project to be completed on a platform raised above ground. High voltage electrical switchgear can be specified as compact and therefore housed inside switchgear buildings that can be aesthetically pleasing and look like a building that blends into the existing community (whether commercial, industrial or office towers). Nowadays, state of the art solutions are available where for example High Voltage compact Gas Insulated Substations (GIS) are installed inside residential housing units. In some cases, the GIS can be pre-assembled and pre-tested in the enclosure before moving it to final pad, facilitating and optimizing civil construction as well as installation and commissioning logistics. Proactive decisions and future refurbishment planning for substations which have been reclassified to be operating in a flood zone are good for utilities to engage in discussion on how to maintain an operating electrical grid for weather related events that include flooding.

2.5 Site specific requirements – reaching communities in urban areas across large rivers.
Urbanization can lead to cities that will encroach on natural boundaries such as a river valley. Utilities that operate distribution systems to new areas across the river will be faced with decisions on how to best provide electrical services. Depending on the size of the river valley, this may present complications with using overhead structures. A river valley for expanding communities is certainly an asset for developing walking and biking paths, but not in favour of overhead electrical distribution systems. There is a solution available which allows for horizontal directional drilling (HDD) distribution circuits in a large diameter steel casing to interconnect communities with the rest of the city electrical distribution system. Such an endeavour would require multi-disciplined engineering efforts coordinated from individual teams such as environmental, geotechnical, civil and electrical. It is important that projects such as these utilize expertise in horizontal directional drilling techniques and design to avoid a "frac-out" (unintentional return of drilling fluids to the surface during HDD construction efforts) situation overland, but most importantly while under the river which is being crossed. Electrical engineers are then faced with the challenge of calculating allowable cable ampacity for circuits which will be crossing at depths that push the limitations of commercially available ampacity software. Cable manufacturers can be of assistance which now have technology available to dynamically monitor cable temperature along the length of cable. This can be particularly useful for distribution control centres to understand how cable loading is affecting overall cable temperature and understand the loading levels at cable thermal limits.

As an alternative to overhead lines and cables the use of GIL (gas-insulated lines for high power AC-transmission) [2] could be considered as well. This technology offers flexibility, environmental friendliness (no SF_6 or F-Gases are used) and with its "line-in-a-can" design that neutralizes inductive current, the AC-GIL generates electromagnetic fields which are 15 – 20 times lower than conventional cables, even meeting upper limits as low as 1 μT.

3. Environment, health and safety considerations - Sustainable solutions for the future

The search for safer and environmentally friendlier substations requires commitment beyond the traditionally accepted standards. Critical electric power infrastructure is expected to remain operational for several decades before it is outdated or has reached the end of its operational life, and as such one should always consider whenever possible design approaches and technical enhancements that enable future upgrades, expansions and adaptations to future standards and requirements. Such enhancements include features that aim at enabling long-term sustainability from an environmental as well as health and safety compliance perspective.

3.1 Transformers insulated with Ester for enhanced fire safety, explosion proof design and mitigation of environmental impacts
A modular innovation architecture allows a comprehensive fire-safe substation concept. This modular concept can be implemented for use on any kind of transmission asset.
The rising demand for energy, as well as changing grid conditions, lead to substations often operating closer to their design limits. This change in the mode of operation can lead to a statistically increased risk for personal safety and for environment incidents. As an example, for this modular approach reference is made to a Siemens Energy modular architecture solution with features that help mitigate environmental impacts resulting from fire and explosion [3].

For transformer tanks to have a rupture-safe design, consideration of the highest possible system fault currents with verified and validated simulation methods to help demonstrate this rupture safety are required and often demanded by operators. The application of static and dynamic FEM simulations to evaluate and optimize the tank's capability to withstand internal arcing are some of the required design methodologies.

The use of Ester fluid insulation (as an alternative to mineral oil), and transformer tanks with an adequate rupture resistance, can mitigate fire and rupture risks for new transformers. This enhanced safety can be enabled using an FM-Global approved K-class liquid which significantly reduces the risk of insulation catching fire due to the higher flash and fire points and because of the lower gas generation rate it has compared to traditional mineral oil. The fire point of mineral oil is about 170°C, however the fire point of Esters is above 316°C. The lower gas generation can increase the capability to withstand tank rupture by about 20%. With a proper selection of components such as non-porcelain bushings and vacuum tap changers, an extended fire safety of the whole transformer system can be achieved.

Besides the higher fire safety offered by Ester insulation (which are FM Global-approved, less flammable fluids), the environmental impact in case of spills is also greatly reduced. Esters are an environmentally friendlier alternative over traditional mineral oils. Ester fluids are readily biodegradable and should spills occur, the environmental impact would be significantly reduced. Tests have been conducted to demonstrate the biodegradation of different insulating liquids. As an example, a 28-day biodegradation test shows that Esters have a biodegradation of 89% or higher compared to mineral oil with that has a biodegradation of less than 10%. [4]

The optimum level of performance and desired protection against known risks (e.g., operational risks, natural disasters and even vandalism) must be evaluated and jointly selected together with the end user/operator. Validated simulations and the verification by tests, even beyond available standards, are the base for special certifications which guarantee the highest availability and overall optimized total cost of ownership.

3.2 Gas Insulated Substations with vacuum switching and no F-gases offer highest environmental protection with zero global warming potential

Gas Insulated Substations (GIS) have traditionally been insulated with SF_6 gas (Sulfur Hexafluoride). While SF_6 is a very good insulating gas due to its electronegativity and density, it is now understood that it is also one of the most powerful greenhouse gases commercially available. SF_6 is about 23,000 times more powerful than CO_2, and because of that, its use is nowadays more regulated, and is starting to be phased out in several regions of the world. SF_6 is an extremely stable man-made gas, and the lifetime in the atmosphere is about 3,200 years. One can for practical purposes assume that any SF_6 gas leaking to the atmosphere will continue to be acting as a greenhouse gas almost forever. Siemens Energy has developed its Blue technology, which does not use SF_6, nor any other Fluorine containing gas and is based on vacuum switching with clean air insulation with the following benefits:

- Clean Air has zero-global warming potential (zero-CO_2-equivalent greenhouse gas).
- As the switching takes place inside a sealed-for-life vacuum bottle, the insulating gas does not decompose during operation (i.e., during the switching operations). There are no toxic by-products.
- Expected product lifetime is more than 50 years with first major inspection after 25 years
- No reporting or emission costs during operation and recycling, e.g., no taxes or CO_2 emission compensation
- As the insulating medium is clean air there is no risk of exposure to changing and increasingly stringent environmental or health and safety regulations
- It is perfect for cold climate applications (no liquefaction takes place even at -50°C)

3.3. Grounding in Urban Environments

All electrical systems require connections to ground, often referred to as earthing. Regardless of how it is described, a grounding or earthing system for a high voltage substation is required and its performance is measured by its connection resistance to remote earth. It is common knowledge that increasing the area of a substation grounding system would result in a lower connection resistance to remote earth. Challenges in maximizing the grounding system performance for a high voltage substation design in urban areas are experienced in the following ways:

(a) Have an existing substation that has aging infrastructure, where an upgrade is warranted. However, design conditions for system fault current levels are larger and it is possible that urban development now exists around the entire substation with commercial or residential property development.
(b) Brand new urban substations are planned in densely populated areas but have limited area and large system fault currents that need to be accounted for in a grounding system design.

Whether there is an existing high voltage substation upgrade, or a brand new compact high voltage substation upgrade, it is important for electrical engineers to understand that small grounding systems can be challenging when addressing the gradient voltages that can exist around the outside of the substation fenced area. There may be architectural features or simply a lack of available real estate which pushes substation fences to the outer property boundaries, limiting any opportunity to have a grounding system placed outside the substation fence. Therefore, it is important that a detailed grounding study be completed to ensure that step and touch voltage safety is within acceptable limits inside the substation for utility employees as well as around the outside of the substation for the general public. Calculations for electrical interference effects such as conductive, capacitive, and inductive interference effects may need to be evaluated by engineers for transient or steady state electrical system operation levels to ensure that electrical effects related to operating a substation in normal and abnormal conditions are within acceptable limits for everyone inside and outside of the substation. The intention for the paper is not to focus on analysis techniques which can be utilized, but to introduce some helpful high level grounding design concepts which may be utilized for high voltage substations which exist in a densely populated urban area.

Completing design for small area substations which are often located in densely populated urban centres can introduce challenges in how to build and install a suitable grounding system. The following examples provided are a few concepts which can be implemented by high voltage substation owners to assist with having step and touch voltages be designed within acceptable threshold voltage limits.

- Non – conductive substation perimeter fence may be useful for instances when gradient control conductor around the outside of the substation fence is not possible. This can be the situation when real estate is limited, and the substation owner chooses to maximize the development area by placing the substation fence on the property line. With this concept, it is important that engineers determine how close the interior buried substation ground grid conductor be installed to the non-conductive fence. Buried substation ground grid conductor during substation ground potential rise (GPR) events create surface gradient voltages which can propagate in an outward direction from the buried grounding system and introduce step voltages around the outside of the substation fence (like dropping a rock into water, largest ripples at the point the rock enters represent the largest gradient voltages nearby the substation grounding system and reduce in magnitude as distance increases). Installing gradient conductor too close to the non-conductive fence can lead to propagating step voltages over the surface of the soil outside the substation fence during GPR events. There needs to be a balance between achieving step voltage protection around the fence perimeter and achieving adequate touch voltage protection inside the substation fenced area. As a result, Engineers must be aware of the surface material that will be used around the outside of a substation in order to ensure that step voltages around the outside of the substation non-conductive fence are within acceptable limits. In some situations, it may be necessary to instal a higher resistivity surface layer material (asphalt) around the inside of the substation fence in order to ensure that utility workers have adequate protection for step and touch voltages.

- It is common to have surface insulating materials (for example insulating gravel that has a specified minimum allowable resistivity) placed around the outside of the substation fence. However, asphalt material which can be specified as decorative can be installed around the substation for a fresh look and also provide wet resistivity characteristics that are approximately three times larger than a typical insulating gravel resistivity.

- Installation of deep driven ground rods or sometimes lowering a ground rod connected to a bare copper conductor into a pre-drilled hole is not a new concept for grounding system design. Many utilities use this method of grounding to allow the grounding system to penetrate deep layers of soil which may be of a lower resistivity and facilitate a method of directing current into deeper layers to limit the amount of surface currents which may normally be dissipated in a GPR event. Mobilizing a drilling rig to site is often the largest deterrent in implementing a grounding system that reaches deep soil layers. However, new ways of project planning can be established and provide clients with opportunities to have value-added options considered with relatively small incremental costs from a normal project. For example, geotechnical work is often required for new substation development, which requires drilling into the deep soil layers to obtain geotechnical information related to the soil structure for civil engineering work. Utilizing the borehole for installing a deep grounding system is an added-value decision which can be pre-planned and utilized later for electrical grounding. The added cost of hiring a utility contractor and material that equals the depth of the borehole will create added value at later stages of the project when grounding system installation is completed, and a deep grounding system is available to connect with. If soil resistivity tests were completed, it is even possible to complete a limited fall of potential test on the installed ground well to help get a much better understanding of how the deep soil resistivity layers might perform in that particular area. These are all excellent opportunities which can lead to making smart decisions later when it comes to establishing grounding system performance.

4. Planning phase

4.1 Early involvement of community

As noted above, much of the infrastructure that is now in need of upgrade, expansion or replacement has been in place for half a century or so, having been designed, manufactured and installed by our grandparent's generation. Furthermore, as also noted, today's generation of industry collaborators are now challenged with the task of performing these upgrades within much more densified and cohesive communities than their predecessors. Almost by definition, this means that both those within the community and those approaching the community are strangers to each other, have social and technical content unknown to each other, and have norms of communication and operation specific to themselves. Therefore, as we approach established communities, we have much ground to make up, much social collateral to build together, in order to come into alignment with each other.

Alignment with each other on the nature of the technical and social challenges to be overcome is critical for progress and success for the infrastructure upgrade. And this alignment is required from a wide array of stakeholders such as individual local residents, community groups, towns / municipalities, parks boards, school districts, health organizations, community interest groups, provincial / territorial political leaders, local business, etc. The list goes on. The solution, of course is to engage with these groups early, but, as significantly, be sure that the dialog is transparent, with nothing hidden or un-addressed, is targeted to the specific needs of the particular community and that it has a consistent message. Each of these aspects are perhaps obviously part of any successful public engagement but success lies in the nuances. For example, with respect to a consistent message it is common that as the community process evolves, an understanding of their needs may shift priorities or otherwise influence the process, or the sequence of elements within the project or might even add or eliminate some aspects of the project. These changes, if not carefully managed can be perceived as changing the project narrative or even not coming through on promises by one group as we seek to come to consensus with all groups. Honesty and timely transparency of process become the critical tools for success as we navigate this inevitable circumstance and others like it.

4.2 Early involvement of sub-suppliers

In our complex world, innovative, sustainable solutions for the future can not be managed by a single scientist or organisation anymore. Innovative solutions can be jointly developed between different faculties and sectors. Therefore, an early involvement of all essential sub-suppliers as partners is recommended and will allow an open and transparent dialog for the development of sustainable solutions for the future.

5. Asset management (operation and maintenance) considering total cost of ownership

5.1 Digitalization with cloud or edge technology– prepared for the future

Digitalization enables operators to optimize the quality and speed of operational decisions, enhancing performance and reliability of the system.

With digital twin models being fed by real time operational data provided by the assets, it is possible to develop very complex algorithms based on artificial intelligence and machine learning to extract useful information in order to maximize equipment usage and for example compute, among others, key parameters like residual lifetime.

Cloud computing provides analysis in an integrated and more reliable system, transitioning from condition-based monitoring and time-based maintenance towards continuous monitoring and predictive operation and maintenance.

Newest advancements in grid edge technology will allow faster and optimised on-premise data processing and computing, enabling further enhancements and new frontiers in the digitalization fields.

5.2 Low maintenance (accessibility of equipment)

In urban areas the power equipment has to be integrated as part of the existing infrastructure and planning of new buildings and other loads. Due to space limitations accessibility for maintenance and any future equipment exchange or upgrade needs to be considered in the wider design approach and choice of materials.

The ultimate goal is to reduce total cost of ownership by reducing planned maintenance work and complete avoidance of any unscheduled outage. Subsequently reduced loss of service times, extension of the lifetime and increased reliability of the assets has to be planned from the very early beginning of the project.

5.3 Risk mitigations for total cost of ownership

High voltage products are investment goods for a reliable and sustainable energy supply of the future. In particular megacities are absolutely dependant on electrical energy and any disturbance would risk human life. Therefore, risk mitigation measures have to be considered not only for the equipment itself. Even more important is an energy supply without any interruption during the entire lifecycle of the equipment as such interruptions might cause substantial additional risks and costs (e.g., evacuation of high-rise buildings) or even endanger human life.

6. Conclusion

Working together as diverse professionals, including engineers, architects, equipment manufacturers, community planners, educators, etc., we can meet the technical demands for power for an evolving population while also addressing the politics, the social concerns, and other needs of long-established urban communities. We can improve resident’s quality of life, while sustaining their ecological context. Faraday, Edison, Yablochkov, Crompton, key inventors and early innovators in this space from around the globe, would be proud of the manner in which society has built on their work of now one to two hundred years ago. Focussed on the long-term refinement, upgrades, and optimization of electrical power source and distribution systems, in the context of ecologically sustainable solutions, one can plan and locate state of the art equipment and technical facilities within our densifying communities such that they operate efficiently until our grandchildren pick up and carry the work forward for their generation.

BIBLIOGRAPHY

[1] Modern Power Systems magazine “Transformers as district heating boilers”, London UK, February 2016. https://www.modernpowersystems.com/features/featuretransformers-as-district-heating-boilers-4816181

[2] Siemens Energy - Gas-Insulated-Lines (GIL) https://assets.new.siemens.com/siemens/assets/api/uuid:11d3c9e0ebde74a60332fe8907cecf2d09300afc/infographic-ac-gil-en.pdf

[3] Siemens Energy - Pretact EcoSafeT™. https://www.siemens-energy.com/global/en/offerings/technical-papers/download-pretact-ecosafet-fire-safe-solution.html

[4] MIDEL®, M&I Materials Ltd company presentation, Biodegradation test, page 25. 2017.

[5] Stantec, 3 challenges – and innovative solutions – when powering urban communities. https://www.linkedin.com/in/glen-kulak-555b4040/detail/recent-activity/shares/

REFERENCES & FURTHER INFORMATION

[All links within this paper had been accessed on July 9, 2021]

https://www.powermag.com/history-of-power-the-evolution-of-the-electric-generation-industry/

https://www.iea.org/data-and-statistics

https://www150.statcan.gc.ca/n1/pub/11-630-x/11-630-x2015004-eng.htm

https://ourworldindata.org/urbanization

https://www.stantec.com/en/ideas/topic/cities/3-challenges-and-innovative-solutions-when-powering-urban-communities

For energy consumption of pools:
https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/benchmarking-rendement/Swimming_Pool-ACC-EN.pdf

For heat loss from electrical equipment:
https://www.engineeringtoolbox.com/heat-gain-equipment-d_1668.html

For heat and hot water energy consumption data of a typical existing apartment building:
https://www.researchgate.net/publication/228487853_Heat_energy_and_water_consumption_in_apartment_buildings

United Nations report on “Percentage of Total Population Living in Coastal Areas”:
https://www.un.org/esa/sustdev/natlinfo/indicators/methodology_sheets/oceans_seas_coasts/pop_coastal_areas.pdf

National Ocean Service, Is sea level rising:
https://oceanservice.noaa.gov/facts/sealevel.html