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Large Scale Energy Storage

Introduction

Greenhouse gas emission reduction is a driving force behind implementation of many renewable energy generation sources such as wind and solar. Depending on weather conditions, power outputs of solar and wind farms vary greatly, making them difficult to predict when the power will be available from the renewable sources. As a result, integration of renewable energy sources to utilities requires complex control since utilities need to continuously match supply with demand. Decoupling energy generation and its usage will require installation of large scale energy storage systems. Both large scale energy storage systems near the renewable power generation sources and at customer sites will allow easy integration of variable sources to the grid.

Types of Energy Storage

Types of energy storage include compressed air; flow batteries; pumped heat; flywheel; and pumped hydro (pumping water up a hill at times of surplus energy, so that we can later to create hydroelectric power during the peak demand). Each of these storage technologies is suitable for certain applications: energy management, backup power, load leveling, frequency regulation, voltage support, and grid stabilization. As a result, energy storage types mentioned above can't meet the demand of all grid applications, requiring storage portfolio strategy. Adoption of different energy storage technologies at different levels of power distribution will increase power system resiliency.

Technology Overview

Presently, pumped hydro comprises 95% of the storage systems installed in the US. Pumped hydro currently employs off-peak electricity to pump water from a reservoir up to another reservoir at a higher elevation. When electricity is needed, water is released from the upper reservoir through a hydroelectric turbine into the lower reservoir to generate electricity. New capabilities of pumped hydro, through the use of variable speed pumping, has the potential for the additional services that may be used to assist in the integration of renewable energy sources. Compressed air energy storage (CAES) stores energy using compressed air, usually in underground caverns, to deliver power when needed at a later time. Large geographic requirements make pumped hydro and CAES installation site specific.

In contrast to the capabilities of these two technologies, various electrochemical batteries and flywheels can address demands at lower power levels with shorter discharge times, ranging from a few seconds to six hours. In addition, these technologies have no geographic constraints.

There are several different electrochemical battery technologies such as lithium ion, sodium sulfur, and lead acid, currently available for commercial applications. Widespread adoption of these technologies is limited due to challenges in energy density, power performance, charging capabilities, safety and system cost.

Flywheels in commercial installations are limited to frequency regulation. Flywheel plants receive electricity and convert it into spinning discs, whose speed is modulated (up or down) to match shifts in energy to or from the grid, which ensures steady power (60 Hz) is supplied to the grid.

Other emerging technologies include: flow batteries, superconductive magnetic energy storage (SMES), electro-chemical capacitors (EC) and thermochemical energy storage.

Distributed Energy Storage

Grid level energy storage will enhance integration of large scale renewable energy sources. Implementation of small scale photo voltaic (PV) systems at customer sites is also creating an opportunity for customer energy storage, improving reliability and increasing economic benefits. For long, uninterruptable power and thermal energy storage systems have been used by customers to increase reliability of electrical systems. The value proposition for installation of distributed energy storage at customer sites depends on the time-of-use rates and demand charges. However, their implementation has the potential of reducing capital expenditures required for installation of additional peak power generation capacities by the utilities.

Conclusion

Reduction of greenhouse gases will require installation of variable power sources, requiring adoption of energy storage systems. Primary barriers to widespread adoption of storage systems include cost, performance, safety, equitable regulatory environment and industry acceptance, with a need to focus on the reduction of these barriers at national and local levels.

References:

[1] Yuri V. Makarov, Michael C.W. Kintner-Meyer, Pengwei Du, Chunlian Jin, and Howard F. Illian, Sizing energy storage to accommodate high penetration of variable energy resources, IEEE Transaction on Renewable Energy, Vol. 3, No. 1, pp 34-40, 2012.

[2] US Department of Energy. Grid Energy Storage, Washington DC, December 2013.

Reducing Arc Flash Risk with Protective Relay

The exposure to an increasingly higher arc flash incident energy fault to technicians operating on low and medium voltage switching equipment is a daily hazard in the workplace. While Personal Protective Equipment (PPE) protects for first and second degrees burns, it does not provide sufficient protection for the impact and forces that a high incident energy arcing fault produces and the associated gases released. Therefore, reduction of the incident energy of the arcing fault is required to improve worker safety.

NFPA 70E defines flash hazard as a dangerous condition associated with the release of energy caused by an electric arc, which occurs due to a short circuit where the fault current is traveling through ionized air. As ionized air provides high resistance path to the conduction of electricity, current flow could be as low as 43% of the bolted three-phase short circuit fault on 480 V buses. Due to long clearing of arcing fault, the resultant intense heat, flying debris or shrapnel, projected molten cooper and gases released from an arcing fault produces a great amount of arc flash byproduct. Faster clearing of an arcing fault reduces caloric energy that is produced, consequently, the less molten material, shrapnel, and gases released.

Applying a modern protection relay protection system with adjustable settings, multiple levels of protection, control, and communication function of the relays can substantially reduce arc flash (AF) incidence. The protection engineer must perform a systemic review of the electrical system to identify normal operation and switching operation, so that arc flash energy and protection level can be identified for each modes of operation. In a typical plant, the power system is normally operated with the tie circuit breakers open, except during switching operations. As a result, arch flash level is higher during the switching operation and AF labels need to be designed to indicate these different operating conditions.

The most important factor that can be controlled is the time-current characteristics of the system protective devices through selecting different curves and settings to reduce the time to clear the arcing fault. Relay adjustment settings are as follows:

a) Pickup: the minimum current at which a device actuates. Lower pickup provides arc fault protection for a greater range of fault currents.
b) Time delay setting: Shorter time delay reduces time to trip and lowers I^2t.
c) Instantaneous pickup: Operating time is typically the minimum possible for the circuit being protected. Lower instantaneous pickup settings reduce arc flash hazard.
d) Coordination Time Intervals: Tightening up coordination time intervals is a direct and simple way of reducing tripping times and thus reducing t for any given current.

Most engineers and many software programs use a 0.3-s minimum coordination time interval between tripping characteristics of series-overcurrent devices; this time interval can be safely reduced to 0.25 sec [1] when using digital protective devices if very specific testing and analysis are performed.

Adjustment of protection settings require that a protection engineer perform short circuit study, coordination study, and modify the settings to achieve lowest AF energy level possible without compromising selectivity. When designed properly, microprocessor based protective relays provide the means to accelerate the extinction of the arc produced by short circuits where the air is the conducting medium.

Appropriate PPE and increasing the distance of personnel from the electrical switchgear are the first line of defense to protect the people from hazardous risks; however, a well maintained electrical system, proper coordination studies and modern protective relays are the perfect companion for a safe working environment.

[1] Leoni, A.R. and Bowen, J., "Improving Safety and Reliability Via Cost-Effective Upgrades of Existing Systems". IEEE Transactions on Industry Applications, Vol. 43, No.1 Jan/Feb 2007.

[2] IEEE 1584-2002, IEEE Guide for performing Arc-Flash hazard calculations.

[3] Standard for Electrical Safety in the Workplace, NFPA 70E, National Fire Protection Association, 2004.

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Designing Flexibility into Laboratory Benches

Overview

The laboratory bench is the primary workplace in most labs. The traditional bench assembly consists of a wide, solid and durable benchtop with sink and utilities, anchored to fixed storage cabinets, with wall mounted shelving or cabinets. The bench assembly provides a researcher with essential elements to work: a large, stable surface for equipment and devices, access to sinks, power, data/ communication and piped services, and ample storage space. Traditional bench assemblies are durable, stable and long-lasting (figure 1).

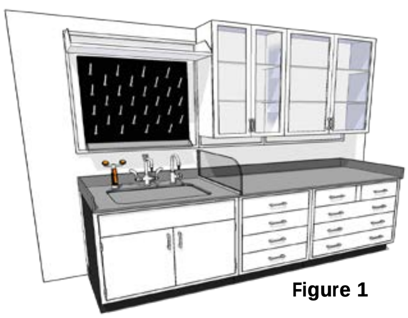
Figure 1

A disadvantage of the traditional bench assembly is that its elements are fixed in place, and any significant modification is a construction project. Although traditional lab casework is nominally modular, modifications require that sections of bench be disassembled by a team of contractors, usually shutting down a lab. Modifications may not be a concern in a lab that has dedicated long-term programs, but may be a continuous fact of life for a lab with changing researchers, methodologies and equipment.

Designing laboratories with a level of flexibility can make the modifications easier, faster and less costly. Typical changes that may occur:

- Moving or removing base cabinets to create under counter knee spaces or equipment space.
- Moving or removing benchtops to create floor space for equipment.
- Raising or lowering benchtops for accessibility, or to change from bench to desk height.
- Removing or adding wall cabinets or shelves.

Flexibility, which will reduce the cost and disruption of minor modifications, can be achieved in a number of ways, using traditional bench systems or flexible bench system.

Traditional Bench Systems

Traditional bench systems can be designed to add a level of flexibility, and allow a degree of modification by lab personnel (figure 2).

- Benchtops can be supported on legs, eliminating fixed base cabinets.
- Base cabinets on wheels can be used under benchtops, allowing base cabinets to be relocated as needed. Mobile base cabinets can be fitted with durable tops, so that they can function as pull-out work surfaces.
- Labs can utilize lab carts and tables in lieu of fixed benches in areas where sinks and the stability of fixed benches are not required.
- Adjustable, removable wall shelves can be used in lieu of fixed cabinets.

If traditional systems are made flexible, the distribution mode of power, data and other services should be considered so that they are equally flexible. Strategies include locating outlets along the walls at regular intervals (high and low) and in the ceiling so that they are accessible to floor and bench mounted equipment in multiple lab configurations. Hard-connected items, including sinks, fume hoods will be fixed elements and should be located strategically at the perimeter of the lab.

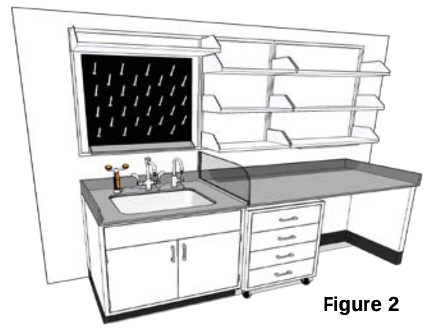
Figure 2

By replacing fixed elements with mobile and movable elements a degree of flexibility can be designed into the lab, most of which can be done by lab staff or maintenance personnel.

Flexible Bench Systems

Flexible bench systems are specifically designed by lab casework manufacturers as interchangeable components which can be modified and reconfigured with relative ease. Systems consist of a steel bench frame supporting an adjustable height benchtop. Base cabinets are typically suspended from the frame. Frames and cabinets are not fixed in place, but on floor glides or locking wheels (figure 3).

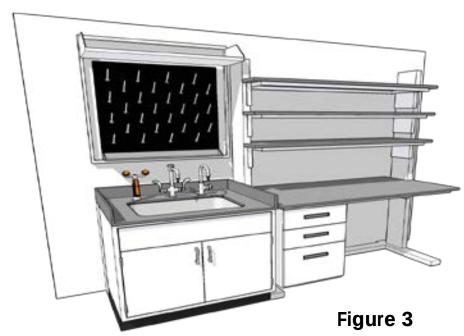
Figure 3

Bench frames have vertical extensions which support adjustable/removable shelves or cabinets, and through which power, data and other services can be routed.

Flexible bench systems components are designed to be reconfigured by lab staff or maintenance personnel, depending on the scope of the modification. Most work can be done quickly, with limited disturbance to lab operations.

Next Issue: Advantages and disadvantages of Flexible Bench Systems.

Added for further reading:

Research Laboratory, Whole Building Design Guide,
http://www.wbdg.org/design/research_lab.php
Trends in Laboratory Design, Whole Building Design Guide,
http://www.wbdg.org/resources/labtrends.php

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Fixed and Flexible Lab Bench Considerations

Overview

The March Technical Bulletin outlined the benefits and some of the options for designing flexibility into laboratory benches. Flexibility is a desirable attribute, but flexibility in benchwork comes with operational and financial tradeoffs which must be understood. The degree of flexibility should be assessed for each application and selected accordingly. This issue will outline some of the advantages and disadvantages of flexible benches.

Flexible System Advantages

Flexible systems provide a number of very useful features not available with traditional fixed benches, including:

Benchtop height adjustability: Most flexible bench systems allow the height of the benchtop to be adjusted from 30" to 36". This adjustability allows individual section of benchtops to be at a specific height required for ABA/ADA compliance (typically 34"), the comfort for an individual researcher, or ideal height for a specific piece of equipment or process. A growing concern is repetitive stress issues facing employees, which can be addressed by providing a wider range of benchtop heights. Flexible bench systems allow benchtop heights to be adjusted with minimal effort.

Bench reconfiguration: Flexible bench systems consist of standard lengths of a table-like frame system on which a benchtop, undercounter cabinets and shelves are connected. Cabinets and shelves can be added or removed, and entire bench section added or removed usually with minor effort, providing layout flexibility, and allowing a lab to be reconfigured as required to meet evolving needs.

Fixed and Flexible System Comparison

Flexible features are associated with a number of limitations which should be weighed against the advantages, to determine the optional system for a particular situation. Items to consider include:

Cost: The first cost of flexible systems is generally significantly higher than standard fixed benchwork. Flexible systems also utilize proprietary components, so parts and service must be obtained from a single supplier, with potential cost implications. The cost of modifying fixed benchwork is very high, however, and can raise the life cycle cost of fixed casework until it meets or exceeds that of flexible systems. Another consideration is that flexible systems may be defined as furniture, as opposed to building components, which may influence depreciation and funding sources.

Storage Efficiency: Standard fixed benches provide a more efficient use of storage space than flexible systems. Flexible systems incorporate frames, guides, adjustment clearances and other aspects of adjustability which reduce efficiency.

Durability: Flexible systems are designed with components which move, which introduces a level of wear to componentry that is not in traditional fixed benchwork.

Stability: Fixed benchwork is immobile and benchtops are large sheets of heavy material (typically epoxy or phenolic resin), anchored to both the casework and the wall. This assembly provides a very stable platform for sensitive work. Flexible systems are supported on locking wheels or floor guides, and are not anchored to the floor or wall, resulting in an assembly that can be unstable. In addition, 'C' frames and cantilevered system can flex under heavy loading.


Figure 1

Seamless Tops: Fixed benches are typically fitted with epoxy or phenolic benchtops. Benchtops are available in 10' or 12' sections, and sections are mechanically fastened and chemically sealed to create benchtops of any length desirable. With backsplashes and sidesplashes, a fixed benchtop provides an ideal continuous surface for working with chemicals and liquids (Figure 1). Flexible systems have individual 5' or 6' benchtop sections, with joints between and around the sections (Figure 2). According to DRM requirements, all benchtop joints must be sealed, presenting a problem for flexible casework.

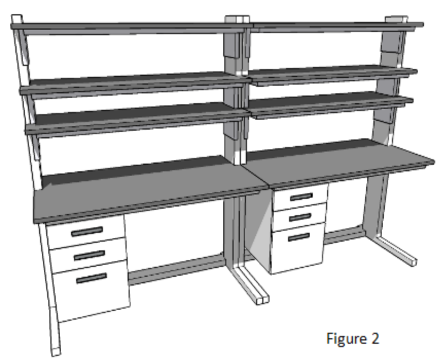
Figure 2

Conclusion

The degree of flexibility should be assessed for each application and selected accordingly. One strategy is to install fixed benches in areas where their characteristics are most useful, including wet areas, areas requiring heavy loading and stable work platforms, and areas not likely to change function. Install flexible benches in 'dry' areas, areas of lighter duty, and areas likely to be reconfigured.

For further reading:
Research Laboratory, Whole Building Design Guide,
http://www.wbdg.org/design/research_lab.php
Trends in Laboratory Design, Whole Building Design Guide,
http://www.wbdg.org/resources/labtrends.php

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Heat Trace (Heat Tracing)

Introduction

Heat trace is most commonly seen with the use of electric heating to protect surfaces and piping from freezing, thus preventing fluid flow due to surrounding low ambient air temperatures. When the heat trace systems are not continuously monitored, their failure can create unpleasant surprises that may negatively impact the systems they serve.

Brief History and Facts

The principle of heat tracing dates back from the early 1900's, when steam and fluid heat tracing techniques, were used to ensure the flow of petroleum (viscosity control) through pipelines. Although very rudimentary during the 1930's, electric heat tracing began to appear without dedicated equipment, controls or adequate materials. After World War II ended, the oil and derivatives industries grew and needed more effective ways to keep up with the demand. In the early 1950's the latest non-electric heat transfer compounds were designed to increase the heat transfer rate, as the industry was looking to maintain lower temperatures with better controls and reliability. Although overwhelmed with problems due to the enlargement and shrinkage of the material and high installation costs, fluid heat tracing (bare tracers), a sort of capillary tubing located above the pipeline, were implemented to lower the amount of heat supplied. During the 1950's durable electric heat tracing was being developed, leading to needed improvements, such as adding temperature controls. This improvement made this technology a serious competitor to the fluid/steam tracer methods.

Equipment Compliance and Types

The steam and fluid heat tracing methods do not have specific guidelines for their implementation; however, all work shall comply with applicable federal, state and local codes as well as industry standards such as ANSI, ASTM, ASME, MSS, UL and API.

The Institute of Electrical and Electronic Engineers, Inc. (IEEE) developed two (2) guidelines for the testing, design, installation and maintenance of electrical resistance heat tracing:

- **IEEE 515**, Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Industrial Applications
- **IEEE 515.1**, Recommended Practice for the Testing, Design, Installation, and Maintenance of Electrical Resistance Heat Tracing for Commercial Applications

Commercial applications of electrical resistance heat tracing for deicing of roof, gutters, pavement, freeze protection of sprinkler piping and standpipe of fire suppression systems in commonplaces are intended for their installation in accordance with the installation guidelines of the NEC, ANSI/NFPA 70 and the IEEE 515.1.
The most common types of electric heat tracing are:

- Heat Tape (for high density and temperature heating)
- Self-Regulating, Low Temperature
- Constant Wattage, Medium Temperature
- Mineral Insulating (for High Temperature)
- Series Resistance and Skin Tracing

Heat Tracing Pros and Cons

Steam heat tracing can utilize waste steam, environmentally safe with high heat transfer rates and practical, if steam source is nearby. However, it is expensive to install if no steam is readily available, has limited operational temperature and has rather unstable temperature control.
Fluid heat tracing can work in a wide temperature range with modest temperature control. It is relatively expensive, requiring a source to heat the fluid, possibly multiple circuits and circulating pump(s) for fluids that can be rather hazardous, if a leak were to occur.
Electric heat tracing can work at almost any location that has electrical power available. It can be installed on short and long metal and non-metal pipes due to the broad range of temperature control and works well on components that require precision temperature control. On the other hand, the electric heat tracing cannot provide quick heat up and could lead to sparking that may lead to fire or explosion, if flammable materials are present, especially when the electrical heat tracing was not properly installed.

Other Applications and Considerations

Heat tracing can also be used in laboratory and industrial applications where necessary for safe and reliable operation of the systems.
In a laboratory environment, heat tracing may be required for pipes and vents exposed to the weather from areas that are considered clean or sterile, such as clean rooms and food processing areas, where some these vents may be equipped with high efficiency particulate air (HEPA) filters. Heat tracing operation should be monitored and alarmed, and powered from an emergency power source.
Heat tracing may be required for control tubing, especially whenever it is exposed to below-freezing outdoor temperatures. Heat tracing is required for extended underground piping for remotely installed grease interceptors, when other options are not available. Piping insulation is also recommended.
Other applications for electric heat tracing (with insulation) include caustic lines in reagent piping systems, hydronic piping, exposed pipe traps, and garage wash-down systems.
For fire protection applications, NFPA 13 allows the use of heat tracing for sprinkler piping in specific areas and conditions, as long as the heat trace is supervised and reliable, unless otherwise not permitted by the authority having jurisdiction.

It is important to again mention that the installation of electric heat tracing follows the IEEE 515 and 515.1 as applicable to ensure reliable and safe operation of the system. Understanding the temperature requirements and the selected product rating, number of circuits required, avoiding cable overlaps, providing proper insulation, grounding, monitoring and controls is very important.
Heat tracing systems can be an asset or a painful nuisance; therefore, understanding the types, options, coordinating with process engineers and plant operators and selecting a good system can maximize the benefits, reduce associated operating cost and improve system reliability.

At NIH, heat trace is certainly the endmost alternative when piped utilities cannot be located within building envelopes and below the frost line (when buried) and should be avoided. Even when supplied from emergency power, heat trace needs to be monitored and alarmed as it is subject to failure from damage, shorting and loss of electrical supply.

Reference:
1. www.thermon.com/catalog/us_pdf_files/tsp0010.pdf
2. www.thermon.com/catalog/us_pdf_files/paf0036.pdf
3. www.heat-trace.com/admin/news/53_SAFETY%20AND%20LONGEVITY%20OF%20SELF-REG.pdf
4. www.interstates.com/img/site_specific/uploads/Heat_Trace_White_Paper.pdf
5. www.edison.com.tr/pdf/sertifika6.pdf
6. http://ulstandards.ul.com/standard/?id=515

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Harmonics

Overview

Harmonics are a mathematical way of describing distortion to a voltage or current waveform. Harmonic voltages and currents in an electric power system are a result of non-linear electric loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems. High levels of harmonic distortion can cause such effects as increased transformer, capacitor, motor and generator heating, mis-operation of electronic equipment, and mis-operation of protective relays. Examples of non-linear loads include common office equipment such as computers and printers, fluorescent lighting, battery chargers and variable frequency drives (VFD). Reduction of harmonics is considered desirable.

In the United States for normal alternating current power systems, the current varies sinusoidally at a specific frequency of 60 Hertz. When a linear electrical load is connected to the system, it draws a sinusoidal current at the same frequency as the voltage (though usually not in phase with the voltage).

Current and Voltage Harmonics

Current harmonics are caused by non-linear loads. When a non-linear load is connected to the system, it draws a current that is not necessarily sinusoidal. The current waveform can become quite complex, depending on the type of load and its interaction with other components of the system. The waveform starts at the power system fundamental frequency and occurs at integer multiples of the fundamental frequency. Voltage harmonics are mostly caused by current harmonics. The voltage provided by the voltage source will be distorted by current harmonics due to source impedance. If the source impedance of the voltage source is small, current harmonics will cause only small voltage harmonics.

Steady-State Distortions

Harmonics are steady-state distortions to current and voltage waves and repeat every cycle. They are different from transient distortions to power systems such as spikes, dips and impulses. Total harmonic distortion (THD) is a common measurement of the level of harmonic distortion present in power systems. THD is defined as the ratio of total harmonics to the value at fundamental frequency.

Power System Harmonics

One of the major effects of power system harmonics is to increase the current in the system. This is particularly the case for the third harmonic, which causes a sharp increase in the zero sequence current, and therefore increases the current in the neutral conductor. This effect can require special consideration in the design of an electric system to serve non-linear loads.

Harmonics Problems

Although the likelihood of harmonic problems is very low, the cases in which they do occur can result in decreasing power system reliability. An understanding of the causes, potential effects and mitigation means for harmonics can help to prevent harmonic related problems at the design stage and reduce the probability of undesired effects occurring during the life of the building. It should be kept in mind that if the harmonic producing loads are small in relation to the total plant load, then harmonics are not an issue. When the non-linear loads become a substantial portion of the total load, it becomes worthwhile to give some consideration to harmonics. In these cases, harmonic modeling analysis is recommended to predict harmonic levels and identify potential problems.

Mitigation for VFDs

For proactive harmonic mitigation for VFDs, NIH states the following prescriptive harmonic allowance limits:

Motor Horsepower	Allowable THD at drive input[1,2] terminals	Allowable iTHD at drive input[2] terminals	Allowable vTHD at drive input[2] terminals	Maximum Individual allowable distortion at any individual harmonic
< 10 Hp	10%	10%	5%	5%
10 Hp to < 25 Hp	8%	8%	5%	4%
25 Hp to < 75 Hp	5%	5%	5%	3%
≥75 Hp	5%	5%	5%	3%

(1) All VFD are required to comply with IEEE519 Table 10.3 for Total Demand Distortion at the Point on Common Coupling (PCC).[3]
(2) Compliance shall be shown for motors loaded between 50% - 100%.
(3) The NIH defined location for the PCC shall be the load side of the building transformer - essentially the switchgear (or main switchboard) bus.

Reference: Rockwell Automation, Allen-Bradley – Power Systems Harmonics: A Reference Guide to Causes, Effects and Corrective Measures. 2001

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Seamless Sheet Flooring in Laboratories

Overview

Seamless floors are used in applications where joints in the flooring are not acceptable. Seamless floors are typically used in biocontainment laboratories, vivariums, clean rooms, clinical use rooms and other spaces requiring cleanliness and/or aseptic conditions, or where high moisture or similar conditions are a concern. Seamless flooring is typically turned vertically up adjacent vertical surfaces, creating integral coved bases at walls, casework and equipment.

There are two categories of seamless flooring: sheet (the focus of this article) and resinous. Resinous flooring are liquid-applied systems (epoxy resin and other polymer based materials) used in vivariums, warehouses, mechanical rooms and other areas subject to extreme wear, wash-down and disinfection. Resinous flooring are installed in a multi-step process over an entire floor area, resulting in a monolithic flooring surface. Resinous floors are hard and durable, but are also expensive, time consuming to install, and difficult to repair.

Sheet Flooring

Sheet flooring is an economical alternative to resinous flooring for many applications. It is manufactured in rolled sheets and adhered directly to the substrate, resulting in a quick, one-step application. Flooring joints are chemically bonded or heat welded, creating a monolithic flooring surface. There are three primary types of sheet flooring, each with distinct advantages and limitations:

Vinyl: Vinyl flooring consists of a PVC or urethane wear layer laminated to a vinyl backing layer. A laboratory grade vinyl floor should have a 20 mil wear layer that is slip and UV resistant and a backing layer that provides a level of resiliency. Vinyl flooring is impervious to water and chemical resistant.

Rubber: Rubber flooring is made from natural or synthetic rubber and may have recycled content. In most forms, it is naturally slip resistant, resilient and antibacterial. Rubber is generally durable and comfortable.

Linoleum: Linoleum is traditional system manufactured from natural materials such as linseed oil, limestone and jute. Linoleum is water resistant (though not impervious), durable and chemical resistant.

Physical Properties

In most laboratory applications the performance of flooring is very important. Each flooring type is available in a range of quality and performance levels, so they should be carefully assessed for suitability for the specific application. During the specification and selection process, the following properties should be considered:

Chemical Resistance: All flooring subject to chemical use shall meet ASTM F925[1] standards, which require testing of materials for resistance to common laboratory chemicals. Additional resistance requirements may be required for unusual applications.

Static Load Limit: All flooring subject to high equipment or other static loading shall be tested to meet ASTM F970[1] standards. This test provides a PSI value for the maximum static floor load that doesn't cause any visual indentation, or create an indentation more than .005". Values of 500 PSI or higher should be considered for high floor-loading areas.

Hardness: All flooring subject to scratching and abrasive wear should have a surface which has been tested to be high on the Mohs hardness scale[2], which ranges from 1 (softest) to 10 (hardest). Vinyl, for example, is available with a wear layer as high as 9.

Underfoot Comfort: A floor's resiliency contributes to the comfort of occupants who may be required to stand for long periods of time. Comfort is not necessarily mutually exclusive with hardness and durability – some sheet vinyl products have a very hard wear layer as well as resilient backing layer.

Water Resistance: All seamless flooring is water resistant, but not all systems are impervious. Excessive water can penetrate and damage linoleum, particularly if it is not resealed periodically.
Additional properties which may be important to the performance of flooring include static dissipation, sound absorption and resistance to high as well as low temperature (thermal shock).

Other Considerations

Other considerations which are important, but which should not outweigh physical properties and performance, include aesthetics, recycled content/recyclability, low VOC of the system (including adhesive), maintenance and cost

For large or complex flooring installations, a mock-up is recommended. The mock-up should include, at a minimum, a welded seam, a section of base, inside and outside corner, and other typical conditions. The mock-up should include adjacent materials to ensure compatibility and to allow review of transition detailing.

In addition to proper selection of flooring materials, the success of any flooring installation will depend on installation. The condition of the substrate, including moisture content and pH, should be reviewed to ensure that they are within manufacturer's recommendations. Cracks, voids and other imperfections in floor substrate should be repaired or mitigated. Manufacturer's requirements for environmental conditions, temperature acclimation of materials, curing times and protection should be followed.

Reference:

[1]ASTM Resilient Floor Covering Standards,
http://www.astm.org/Standards/resilient-floor-covering-standards.html

[2] Mohs Hardness Scale,
http://geology.com/minerals/mohs-hardness-scale.shtml

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Buildings of the Future

Introduction

For many centuries, people have been building shelters to provide comfortable as well as safe living spaces for them. Modern day buildings achieve the same goal of providing human comfort and safety by integrating complex engineered systems including lighting, heating, ventilation, air conditioning, daylighting, security, etc. Over time, each of these building systems has been perfected to increase human comfort, safety and productivity. Today, building designer must embark on a different course to design smart buildings that provide comfortable, secure, productive and enjoyable environment with the least impact to the surrounding environment over the entire life cycle of the structure so that this habitat for humanity remains livable for generations to come.

Smart Building Features

Smart buildings of the futures will leverage the information technologies to allow the flow of information among many subsystems. Sharing of information among many subsystems is now possible as manufacturers has adopted standardized communication protocol such as BACnet®, Modbus®, and LonWorks®, enabling the entire system to function as a complete unit. As an example, occupancy data from security systems can be used to schedule cooling/heating cycle based on actual demand and control lighting based on the same data.

Smart buildings of the future will also share information with systems outside their four walls, enabling a smart electrical grid to evolve. Two way communication between the grid and buildings will empower grid operators, building occupants, and other stake holders to make informed decisions.

Smart Building Technologies

The key enabling technologies of the smart buildings will be internet of things (IOT). IOT will create an intelligent, invisible network that can be sensed, programmed and controlled. IOT-enabled products will be able to communicate directly or indirectly with each other and/or the internet.

By 2020, there will be an estimated 50 billion IOT-enabled appliances and sensors deployed worldwide. These sensors will collect a wide range of data including movement of occupants, heat, light, use of space, medical emergency, intrusion, etc. Data from the sensors can be analyzed for building management systems to make reactive, anticipatory, and personalized alterations to suit the occupants.

Widespread adoption of smart sensors will require that these sensors must be incredibly cheap, consume very little power and be easy to integrate. Wireless sensors are the ideal candidate to meet these requirements. While the costs of wireless sensors have decreased substantially in recent years, reduction of power consumption remains the biggest obstacle. Adoption of new communication protocols and energy harvesting technologies will enable their ubiquitous adoption just like wireless routers in home networking systems today.

Benefits of Smart Building

Smart building will be able to reduce operating costs and enhance satisfaction of the building occupants. There are various ways that a smart building can save money:

- *Matching occupancy patterns to energy use* – Smart buildings will consume less energy when the number of occupants in the building is lower.
- *Optimized cooling and ventilation equipment* –The control system will provide the optimized comfort level desired by modelling the load dynamically at a minimum cost.
- *Proactive maintenance of equipment* – Using analysis algorithms, the system will detect problems in performance before they cause expensive outages, maintaining optimum efficiency throughout the entire life of the system.
- *Dynamic power consumption* – Smart buildings will ensure the lowest possible energy costs by altering usage in response to the market signals from the electricity providers.

Conclusion

Modern buildings have become more efficient and sustainable. However, building a smart community will require implementation of smart building features in both existing and new buildings. Smart building technologies will truly transform how we live, work and play. It will reduce our carbon footprint, increase our productivity, reduce risk of physical injury, and enhance our physical well-being. Smart building technologies along with human ingenuity will be the foundation of our robust, low carbon economy of the future, ensuring a livable environment for posterity.

References:

[1] Smart Buildings, Royal Academy of Engineering, 2013.

[2] A smarter Grid with the Internet of Things, Texas Instruments White Paper, October 2013.

[3] Smart Buildings, Francesco Asdrubali, University of Perugia, Italy, February 2013

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Electrical Working Clearances

Overview

Access and working space shall be provided and maintained about all electrical equipment to permit ready and safe operation and maintenance of such equipment.

Working Space Depth

Working space for equipment operating at 600 volts (V), nominal, or less to ground and likely to require examination, adjustment, servicing, or maintenance while energized shall comply with the dimensions based on the nominal voltage to ground and various conditions for having exposed live parts on one side, with either no live or grounded parts on the other side, grounded parts on the other side, or exposed live parts on the other side. The minimum required working depth is 3' regardless of condition or voltage level, with a minimum depth of 3'-6" for grounded parts and 4' for live parts on opposite sides where the nominal voltage to ground exceeds 151V. Working space shall not be required in the back or sides of assemblies, such as dead-front switchboards, switchgear, or motor control centers, where all connections and all renewable or adjustable parts, such as fuses or switches, are accessible from locations other than the back or sides. Where rear access is required to work on nonelectrical parts on the back of enclosed equipment, a minimum horizontal working space of 30" shall be provided.

In existing buildings where electrical equipment is being replaced, minimum 3' working clearance shall be permitted for nominal voltage to ground less than 151V or 3'-6" for nominal voltage to ground greater than 150V between dead-front switchboards, switchgear, panelboards, or motor control centers located across the aisle from each other where conditions of maintenance and supervision ensure that written procedures have been adopted to prohibit equipment on both sides of the aisle from being open at the same time and qualified persons who are authorized will service the installation.

Working Space Width

The width of the working space in front of the electrical equipment shall be the width of the equipment or 30", whichever is greater. In all cases, the work space shall permit at least a 90 degree opening of equipment doors or hinged panels.

Work Space Height

The work space shall be clear and extend from the grade, floor, or platform to a height of 6'-6" or the height of the equipment, whichever is greater. Within the height requirements of this section, other equipment that is associated with the electrical installation and is located above or below the electrical equipment shall be permitted to extend not more than 6" beyond the front of the electrical equipment.

Clear Spaces

The working space required shall not be used for storage. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be suitably guarded.

Entrance to and Egress from Working Space

At least one entrance of sufficient area shall be provided to give access to and egress from working space about electrical equipment. For equipment rated 1200 amperes or more and over 6' wide that contains overcurrent devices, switching devices, or control devices, there shall be one entrance to and egress from the required working space not less than 24" wide and 6'-6" high at each end of the working space. A single entrance to and egress from the required working space shall be permitted where the location permits a continuous and unobstructed way of egress travel or where the depth of the working space is twice that required as previously indicated.

Dedicated Electrical Spaces

The space equal to the width and depth of the equipment and extending from the floor to a height of 6' above the equipment or to the structural ceiling, whichever is lower, shall be dedicated to the electrical installation. No piping, ducts, leak protection apparatus, or other equipment foreign to the electrical installation shall be located in this zone. The area above this dedicated space shall be permitted to contain foreign systems, provided protection is installed to avoid damage to the electrical equipment from condensation, leaks, or breaks in such foreign systems.

Special Considerations

NIH includes the following special considerations for installations of busways. Install busways such that there is an adequate code required clearance for the current and future plug-in devices. Maintain access to all joints for infrared scanning and possible re-torquing of connections. Busways should avoid running directly beneath and parallel with piping and ductwork, except where crossing situations are required. Busway shall be "drip-proof" for horizontal and vertical applications where busway run beneath piping, or vessels containing liquids, or ductwork. Despite the use of drip-proof busway for these installations, also protect with a deflection drip shield.

NIH includes the following special consideration for installations of variable frequency drives (VFDs). In additional to required working clearances, when VFDs are installed below piping or ductwork, they shall be protected with a deflection drip shield.

References: National Electrical Code (NEC), NFPA 70, National Fire Protection Association, 2014.
National Institutes of Health (NIH) Design Requirements Manual, 2015 (draft)

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Landscape Design with Native Plant Species

Overview

Many construction projects impact their site to some extent, often requiring modifications to the landscape. The landscape is an integral and highly visible part of the built environment, and as such has to be as thoughtfully designed and maintained as other aspects of the project.

An important aspect of landscape design is the use and maintenance of native, non-invasive plant species. Designers should be cognizant of the benefits of native plants and the negative effects that invasive plant species can have on a site's ecosystem.

The U.S. Department of Agriculture (USDA) defines a native plant species as *a plant that is a part of the balance of nature that has developed over hundreds or thousands of years in a particular region or ecosystem*[1].

An Executive Order defines an invasive plant species as *a species that is 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health*[2].

The Impact of Invasive Species

Most invasive plant species have been introduced into ecosystems by humans, either accidentally or purposefully, from outside of the region. This frequently occurred as many invasive plants are found to be attractive or useful. Unfortunately, the presence of invasive species can be detrimental to their new ecosystem in a number of ways, including:

- Reducing native biological diversity by displacing native species.
- Diluting the genetic composition of native species through hybridization.
- Reducing food sources and habitat for native insects and animals.
- Adding to the competition for native pollinators.

The USDA has estimated that invasive species have contributed to the decline of 42% of U.S. endangered and threatened species[3]; as such it is important that designers are meticulous in selecting appropriate plants for a given project.

Design with Native Species

The design of landscape with native plant species should be thoughtful and the designer should recognize of the impact of the plants on the functional aspects of a site. Some general design tenets for using native plants include:

- Avoid dense groundcover which may provide harborage for rodents.
- Avoid dense planting at building foundations which can reduce air circulation and obstruct pest management activities.
- Avoid plants which attract deer.
- Follow existing Master Plan and other guidance standards.
- Coordinate with maintenance, grounds-keeping, and other activities.

Designing with native species provides numerous benefits to a site's users, owners, and ecosystem. One of these benefits is a reduction in maintenance, because native plants have adapted to local environmental conditions, and generally require less fertilizer, pest control, and irrigation than invasive species.

Native species vary through each region of the country and are unique to individual ecosystems. The US Fish and Wildlife Service, the Maryland Department of Natural Resources, the Maryland Native Plant Society and other resources are available to provide information about native plant species for facilities in Maryland. Site-specific information should be obtained for projects in other locations. Early consultation with local landscape architects and designers knowledgeable of native species can be beneficial for a project's development.

Figure 1: Native Plant of Maryland

Scientific Name: Itea Virginica
Common Name: Virginia Sweetspire

Other Considerations

LEED Credit: In recognition of the environmental benefits of native species, LEED points are available for protecting or restoring a project's habitat with native species. Points may also be available for landscaping with native species which do not require irrigation.

Green Roofs: Sedums and other plants often used on green roofs are generally not native but are selected for their ability to live in a minimal depth of growth medium for long periods without water. Designers should recognize the impact of green roofs on the larger ecosystem and consider green roofs specifically designed to support native plant species.

References:

[1] http://www.nrcs.usda.gov/wps/portal/nrcs/detail/ct/technical/ecoscience/invasive/?cid=nrcs142p2_011124

[2] Presidential Executive Order 13112 (February 1999)

[3] http://www.fs.fed.us/wildflowers/invasives

Further Reading

Maryland Department of Natural Resources
http://dnr.maryland.gov/naturalresource/spring2005/landscaping.asp
Maryland Native Plant Society
http://www.mdflora.org
North American Native Plant Society
http://www.nanps.org
National Park Service
www.nps.gov/plants/pubs/nativesmd/lists.htm

Laboratory Exhaust Manifolds

Overview

When searching for ways to save on laboratory exhaust system construction cost and looking to save energy in the process, manifolding laboratory components is one strategy that should be considered. Connecting multiple fume hoods to a common exhaust duct, and having a centralized exhaust fan with an appropriately redundant fan, will contribute to cost and energy reduction goals. Careful selection of system components and controls as well as a close evaluation of the functions and operating conditions are essential.

Intended Benefits

When laboratory exhaust components are manifolded, there are multiple benefits in comparison to individually exhausted systems, including:

- Increased redundancy
- Greater personnel Safety
- Augmented exhaust fume dilution
- Better opportunity for flexible design changes
- Reduce equipment capacity of the exhaust system

On the energy side, other benefits include:

- Less number of fan installations
- Less energy needed to exhaust through the exhaust stack, as dilution may have occurred upstream of the exhaust fan
- Due to the manifolded equipment; larger airflow may potentially be used as a source for energy recovery
- Lower energy usage when variable air volume (VAV) hoods and variable speed drives are used due to smaller exhaust system

Evaluation of the Design Parameters

There are several factors that need to be evaluated when manifolding laboratory exhaust systems. In general, fume hood exhaust shall not be combined with general exhaust unless the exhaust streams are compatible. Under such conditions, the fume hoods and general exhaust may be combined only after penetrating the last fire partition on the floor or if the devices are served from the same laboratory unit. Due to the variety of work performed at each laboratory hood, establishing the type and quantity of chemicals and other toxic elements that require exhaust and dilution, can be extremely difficult. In a multiple manifolded hood system, one or more fume hoods may be operating at any given time. As a result, when using (VAV) hoods, the dilution may not occur as expected. The diversity factor for (VAV) hoods shall be based on the usage and should be evaluated with user and with approval of DOHS. The diversity factor shall not be less than 70%. The image in the Figure 1 shows multiple (VAV) fume hoods manifolded to a single header exhaust ductwork connected to a single exhaust fan also called a Weiber Manifold Fume Hood[1]. Although this arrangement can save energy, it does not provide redundancy due to the single fan operation as required by DRM.

Figure 1: Manifold, Single Fan

Figure 2[2] shows similarly manifolded fume hoods operating as a constant volume system with two single-stage centrifugal fans manifold to a single stack. Although the DRM requires separate stacks, exception when fans are operating 50% capacity are permitted. Although there may be provisions for redundancy, there are no provisions for energy savings. The design of a stack with dual exhaust fans requires further performance evaluation, whether it is designed for one fan to operate a full capacity or both fans operating a partial capacity, allowing full redundancy.

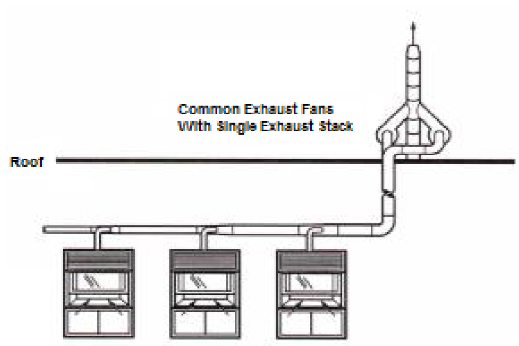

Figure 2: Manifold, Redundant Fans

In both cases, the airflow within the stack may not be stable, generating additional static pressure that will need to be evaluated in order to determine the additional energy required to maintain the minimum stack velocity, approximately 3,000 feet per minute. Depending on the system and requirements, an alternate option to the two single-stage centrifugal fans shown in Figure 2 is the use of high plume dilution fans as shown in Figure 3 that can provide a more compact and efficient system.

Figure 3: High Plume Dilution Fans

Conclusion

When laboratory exhaust system is required, coordination with the architect and the authority having jurisdiction is necessary to ensure that the latest codes and regulations are followed during the design.

Combining exhaust fans into one stack configuration will require close performance evaluation to ensure efficiency, safety and reliability. Regardless of the exhaust fan configuration selected, the roof area needs to be evaluated to allow for guy wires and accessibility for service.

Reference and Further Reading:

(1) http://www.cleanroom-equipments.com/dealer/Fume-Hood-Manifold-System.html
(2) Laboratories for the 21st Century: Best Practice Guide – Manifolding Laboratory Exhaust systems, April 2007, pp 4-6
(3) http://ateam.lbl.gov/Design-Guide/DGToc.htm
(4) Industrial Ventilation: A Manual of Recommended Practice, 22nd Edition, American Conference of Governmental Industrial Hygienists, Inc., 1995.
(5) ASHRAE Journal, (Vol. 47, No. 7, July 2005).

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Porous Concrete Systems

Overview

Porous concrete (also called pervious concrete, permeable concrete, no fines concrete and porous pavement) can be an effective way of reducing the impervious area of a building site. Porous concrete is specifically designed to allow water to pass through site flatwork (roads and sidewalks) and reduce the volume and velocity of stormwater delivered to storm sewer systems, reducing erosion and the need for stormwater retention measures. Porous concrete is traditionally used in parking areas, roads with light traffic, pedestrian walkways, and greenhouses. Porous concrete should not be used on primary roads, fire lanes, loading docks and other areas subject to heavy vehicles.

Porous concrete is made using large, uniform, open-graded coarse aggregates with little to no fine aggregates along with specially formulated mixtures of Portland cement, resulting in a 15% to 20% void spaces.[3] The first known use of porous concrete spans back to the 19th century in Europe; however, it was not until the last few decades that porous concrete has been used in the United States.[2] Much of this recent surge in popularity is due to porous concrete's sustainability benefits in construction and low impact development.

Benefits and Drawbacks

The benefits of using porous concrete include:

- Filtering stormwater thereby reducing contaminants and pollutants.
- Reducing erosion by significantly reducing runoff from parking and other paved areas.
- Reducing the need for curbing and storm sewers. May save on site retention / detention structures, swales and ponds, reducing project costs and providing land for other uses.
- Improving road safety due to better skid resistance.
- Helping with recharging of local aquifers.
- Providing potential LEED credits to assist with project sustainability goals: Credit SS-C6.1 (Storm Water Management – Rate and Quantity), Credit SS-C6.2 (Storm Water Management – Quantity Control) and Credit SS-C7.1 (Landscape and Exterior Design to Reduce Heat Island Effect).

Drawbacks of porous concrete include:

- Permeability may be reduced if improperly installed or not properly maintained.
- There is risk of groundwater contamination due to fuel leaks from cars and leaching of chemicals from binder surfaces within porous systems.
- Potential for the development of anaerobic conditions in soils underlying pervious systems if soils are unable to dry out between storm events.
- Lower compressive strength than standard concrete which does not allow for heavy vehicle traffic.
- Raveling may occur over time and require regular concrete ribbons along edges.
- Freeze / thaw spalling can develop in northern climates exposed to extreme cold temperatures.
- Many engineers and contractors still lack expertise and experience with this technology.
- First cost is higher than standard concrete applications, but may be offset by reduced needs of stormwater management installations.

Design Criteria & Maintenance

Site conditions are of critical importance for a properly functioning and designed application of porous concrete systems. Systems should be located above soils which have a field-verified permeability rate of greater than 1.3 centimeters (0.5 inches) per hour and have a 1.2 meter (4 foot) minimum clearance from the bottom of the system to bedrock or the water table.[1] Sites prone to wind erosion of soils and sediments should be avoided. Flat sites are greatly preferred and systems are not recommended to be installed in areas where slopes are greater than 5%.[1] When used for automobile applications porous concrete should be installed for light traffic and low volumes of automobiles. Avoid locations which may require snow removal operations. Additional consideration should be given to the local climate and weather conditions throughout the seasons. It is generally recommended that these systems are designed to be capable of draining a 6 month, 24 hour storm event within 24 hours.[1]

In addition to routine inspection it is necessary to perform diligent maintenance on porous concrete systems. Maintenance is required to prevent clogging of the concrete pores and loss of permeability. Recommended maintenance operations include vacuum sweeping a minimum of four times a year in conjunction with high-pressure washing.[2] Inspections should occur after large storm events to identify any clogging or water buildup.

Conclusion

Porous concrete systems can provide significant environmental and potential cost benefits when compared to traditional concrete in similar applications if properly designed, installed, and maintained. This is a relatively new technology to the United States, so designers should be diligent in investigating benefits, drawbacks and site conditions early to ensure system applicability and success.

References

[1] Storm Water Technology Fact Sheet: Porous Pavement". United States Environmental Protection Agency, EPA 832-F-99-023, September 1999.

[2] Chopra, Manoj. "Compressive Strength of Pervious Concrete Pavements" (PDF). Florida Department of Transportation. Retrieved 1 October 2012.

[3] John T. Kevern, Vernon R. Schaefer, and Kejin Wang (2011)."Mixture Proportion Development and Performance Evaluation of Pervious Concrete for Overlay Applications". Materials Journal (American Concrete Institute) 108 (4): 439–448.