Project

BUILDING INFORMATION OF MODELLING

Submitted in partial fulfillment of the requirements for the award of
Third Year Diploma

In

Civil Engineering

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2020-21

ACKNOWLEDGEMENT

I would like to extend my gratitude towards our college Guru Gobind Singh Polytechnic for providing us this opportunity to study in such a wonderful Institution. Secondly, I would like to thank our HOD, Mr. G.D.Ahire sir for helping us in our difficulties. Thirdly, I would like to thank our public health engineering sir, Prof.Gaurav Ahire. sir for guiding and helping me in every difficulty I faced. Lastly, I would like to thank my parents for their guidance and support without which this project would not have been accomplished.

GURU GOBIND SINGH POLYTECHNIC, NASHIK

CIVIL DEPARTMENT

CERTIFICATE

Certificate That the Micro Project Report Entitled

BUILDING INFORMATION

OF MODELLING

SUBMITTED BY

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As partial fulfillment of Third Diploma Course Civil Engineering under the Maharashtra State Board of Technical Education, Mumbai during the academic year (2020-2021).

The said work has been assessed by us and we are satisfied that the same is up to the standard envisaged for the level of the course. And that the said work may be presented to the external examiner.

Prof. Sagar Shinde Prof. P.G. Chavan

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INTRODUTION

To better understand the signifi cant changes that BIM introduces, this chapter

BIM A Guide to Building InformationModeling for Owners, Managers,Designers, Engineers, and Contractors.Chuck Eastman, Paul Teicholz, Rafael Sacks and Kathleen Liston Copyright © 2008 John Wiley & Sons, Inc.methods and the predominant business models now in use by the constructionindustry. It then describes various problems associated with these practices,outlines what BIM is, and explains how it differs from 2D and 3D computer -aided design (CAD). We give a brief description of the kinds of problems thatBIM can solve and the new business models that it enables. The chapter con-cludes with a presentation of the most signifi cant problems that may arise when using the technology, which is now only in its earliest phase of develop-ment and use.

BIM : NEW TOOLS AND NEW PROCESSES

This section gives an overall description of BIM - related terminology, concepts,and functional capabilities; and it addresses how these tools can improve business processes. Specifi c topics are discussed in further detail in the chaptersindicated in parenthesis.BIM Model Creation Tools

All CAD systems generate digital fi les. Older CAD systems produce plotteddrawings. They generate fi les that consist primarily of vectors, associatedline - types, and layer identifi cations. As these systems were further devel-oped, additional information was added to these fi les to allow for blocks ofdata and associated text. With the introduction of 3D modeling, advanceddefi nition and complex surfacing tools were added.As CAD systems became more intelligent and more users wanted to sharedata associated with a given design, the focus shifted from drawings and 3Dimages to the data itself.

A building model produced by a BIM tool can supportmultiple different views of the data contained within a drawing set, including2D and 3D. A building model can be described by its content (what objects itTable 1-1 Additional costs of inadequate interoperability in the constructionindustry, 2002 (in $millions).Stakeholder GroupPlanning, Engineering,Design Phase Construction PhaseO&MPhaseTotalAdded CostArchitects andEngineers$1,007.2 $147.0 $15.7 $1,169.8General Contractors $485.9 $1,265.3 $50.4 $1,801.6Special Contractorsand Suppliers$442.4 $1,762.2 $2,204.6Owners anOperators$722.8 $898.0 $9,027.2 $1,0648.0Total $2,658.3 $4,072.4 $9,093.3 $15,824.0Applicable sf in 2002 1.1 billion 1.1 billion 39 billion n/aAdded cost/sf $2.42/sf $3.70/sf $0.23/sf n/aSource: Table 6-1 NIST study (Gallaher et al. 2004).12 Chapter 1 BIM Handbook Introductionc01.indd Sec2:12 12/19/07 1:51:50 PMdescribes) or its capabilities (what kinds of information requirements it cansupport).

The latter approach is preferable, because it defi nes what you can dowith the model rather than how the database is constructed (which willvary with each implementation).BIM: New Tools and New Processes For the purpose of this book, we defi ne BIM as a modeling technologyand associated set of processes to produce, communicate, and analyzebuilding models. Building models are characterized by:Building components that are represented with intelligent digital repre-sentations (objects) that 'know' what they are, and can be associatedBuilding components that are represented with intelligent digital repre-sentations (objects) that 'know' what they are, and can be associatwith computable graphic and data attributes and parametric rules.Components that include data that describe how they behave, asneeded for analyses and work processes, e.g., takeoff, specifi cation,and energy analysis.Consistent and non-redundant data such that changes to componentdata are represented in all views of the component.Coordinated data such that all views of a model are represented ina coordinated way.The following is a defi nition of BIM technology provided by the M.A.Mortenson Company, a construction contracting fi rm that has used BIM toolsextensively within their practice (Campbell 2006).Mortenson's Defi nition of BIM TechnologyBIM has its roots in computer-aided design research from decades ago, yet it stillhas no single, widely-accepted defi nition. We at the M.A. Mortenson Companythink of it as "an intelligent simulation of architecture.

" To enable us to achieveintegrated delivery, this simulation must exhibit six key characteristics. It must be:Measurable (quantifi able, dimension-able, and query-able),Comprehensive (encapsulating and communicating design intent, build-ing performance, constructability, and include sequential and fi nancialaspects of means and methods),Accessible (to the entire AEC/ owner team through an interoperable andintuitive interface), andDurable (usable through all phases of a facility's life).c01.indd Sec3:13 12/19/07 1:51:50 PMIn light of these defi nitions, one might argue that few design or construc-tion teams are truly using BIM today. In fact, we may not achieve this highstandard for several years. But we believe these characteristics are all essentialfor reaching the goal of integrated practice.Furthermore,there are no current implementations of BIM software thatmeet all of the BIM technology criteria. Over time, the capabilities will grow aswill the ability to support better and more extensive practices. The list in thefollowing section is intended to provide a starting point for evaluating specifi cBIM software tools. See Chapter 2for more detailed information about BIMtechnology and an analysis of current BIM tools.Defi nition of Parametric Objects (Chapter 2)The concept of parametric objects is central to understanding BIM and itsdifferentiation from traditional 2D objects.

Parametric BIM objects are defi nedas follows:consist of geometric defi nitions and associated data and rules.geometry is integrated non-redundantly, and allows for no inconsisten-cies. When an object is shown in 3D, the shape cannot be representeinternally redundantly, for example as multiple 2D views. A plan andelevation of a given object must always be consistent. Dimensions can-not be 'fudged'.Parametric rules for objects automatically modify associated geometrieswhen inserted into a building model or when changes are made to associ-

WHAT IS NOT BIM TECHNOLOGY

The term BIM is a popular buzz word used by software developers to describethe capabilities that their products offer. As such, the defi nition of what consti-tutes BIM technology is subject to variation and confusion. To deal with thisconfusion, it is useful to describe modeling solutions that DO NOT utilize BIMtechnology. These include tools that create the following kinds of models:Models that contain 3D data only and no object attributes. These aremodels that can only be used for graphic visualizations and have no intel-ligence at the object level. They are fi ne for visualization but provide nosupport for data integration and design analysis.What Is Not BIM Technology 15c01.indd Sec4:15 12/19/07 1:51:51 PMModels with no support of behavior.

These are models that defi ne objectsbut cannot adjust their positioning or proportions because they do notutilize parametric intelligence. This makes changes extremely labor inten-sive and provides no protection against creating inconsistent or inaccurateviews of the model.Models that are composed of multiple 2D CAD reference fi les that mustbe combined to defi ne the building. It is impossible to ensure that theresulting 3D model will be feasible, consistent, countable, and displayintelligence with respect to the objects contained within it.Models that allow changes to dimensions in one view that are not auto-matically refl ected in other views. This allows for errors in the model thatare very diffi cult to detect (similar to overriding a formula with a manualentry in a spreadsheet).

WHAT ARE THE BENEFITS OF BIM ? WHAT

PROBLEMS DOES IT ADDRESS?

BIM technology can support and improve many business practices. Althoughthe AEC/FM (Facility Management) industry is in the early days of BIM use,signifi cant improvements have already been realized (compared to traditional2D CAD or paper - based practices). Though it is unlikely that all of the advan-tages discussed below are currently in use, we have listed them to show theentire scope of changes that can be expected as BIM technology develops.

Pre - Construction Benefi ts to Owner

Concept, Feasibility and Design Benefi tsBefore owners engage an architect, it is necessary to determine whether abuilding of a given size, quality level, and desired program requirements can bebuilt within a given cost and time budget, i.e. can a given building meet thefi nancial requirements of an owner. If these questions can be answered withrelative certainty, owners can then proceed with the expectation that their goalsare achievable. Finding out that a particular design is signifi cantly over budgetafter a considerable amount of time and effort has been expended is wasteful.An approximate (or macro) building model built into and linked to a costatabase can be of tremendous value and assistance to an owner. This isdescribed in further detail in Chapter 4and illustrated in the HillwoodCommercial Project case study in Chapter 9 .16 Chapter 1 BIM Handbook Introductionc01.indd Sec4:16 12/19/07 1:51:52 PMIncreased Building Performance and QualityDeveloping a schematic model prior to generating a detailed building modelallows for a more careful evaluation of the proposed scheme to determinewhether it meets the building ’ s functional and sustainable requirements. Earlyevaluation of design alternatives using analysis/simulation tools increases theoverall quality of the building.

wDesign Benefi ts

Earlier and More Accurate Visualizations of a DesignThe 3D model generated by the BIM software is designed directly rather thanbeing generated from multiple 2D views. It can be used to visualize the designat any stage of the process with the expectation that it will be dimensionallyconsistent in every view.Automatic Low - Level Corrections When Changes Are Made to DesignIf the objects used in the design are controlled by parametric rules that ensureproper alignment, then the 3D model will be constructible. This reduces theuser ' s need to manage design changes (see Chapter 2for further discussion ofparametric rules).Generate Accurate and Consistent 2D Drawings at Any Stage of the DesignAccurate and consistent drawings can be extracted for any set of objects orspecifi ed view of the project. This signifi cantly reduces the amount of time andnumber of errors associated with generating construction drawings for alldesign disciplines. When changes to the design are required, fully consistentdrawings can be generated as soon as the design modifi cations are entered.Earlier Collaboration of Multiple Design DisciplinesBIM technology facilitates simultaneous work by multiple design disciplines.While collaboration with drawings is also possible, it is inherently more diffi cultand time consuming than working with one or more coordinated 3D models †in which change - control can be well managed. This shortens the design timeand signifi cantly reduces design errors and omissions. It also gives earlierinsight into design problems and presents opportunities for a design to be con-tinuously improved. This is much more cost effective than waiting until a

What Are the Benefi ts of BIM, What Problems Does It Address?

If a BIM system does not use a single database, which can create problems for very large and/orfi nely detailed projects,alternative approaches involving automatic coordination of multiple fi lescan also be used. This is an important implementation issue for software vendors. (See Chapter 2for more discussion of model size issues).c01.indd Sec5:17 design is nearly complete and then applying value engineeringonly after themajor design decisions have been made.Easily Check against the Design IntentBIM provides earlier 3D visualizations and quantifi es the area of spaces andother material quantities, allowing for earlier and more accurate cost estimates.For technical buildings (labs, hospitals, etc.), the design intent is often defi nedquantitatively, and this allows a building model to be used to check for theserequirements. For qualitative requirements (this space should be near another,etc.), the 3D model can support automatic evaluations.Extract Cost Estimates during the Design StageAt any stage of the design, BIM technology can extract an accurate bill of quan-tities and spaces that can be used for cost estimation. In the early stages of adesign, cost estimates are based primarily on the unit cost per square foot. Ashe design progresses, more detailed quantities are available and can be usedfor more accurate and detailed cost estimates. It is possible to keep all partiesaware of the cost implications associated with a given design before it progressesto the level of detailing required of construction bids. At the fi nal stage ofdesign, an estimate based on the quantities for all the objects contained withinthe model allows for the preparation of a more accurate fi nal cost estimate. Asa result, it is possible to make better informed design decisions regarding costsusing BIM rather than a paper - based system.Improve Energy Effi ciency and SustainabilityLinking the building model to energy analysis tools allows evaluation of during the early design phases. This is not possible using traditional 2D toolswhich require that a separate energy analysis beperformed at the end of the designprocess thus reducing the opportunities for modifi cations that could improve thebuilding ' s energy performance. The capability to link the building model to varioustypes of analysis tools provides many opportunities to improve building quality.

How Software Algorithms and Robotics Will Drastically Change the Design/Build Process

With advancements in generative design, software algorithms, and robotic construction, our current processes are going to be changing quite a bit over the next three to ten years. We will see more and more done by computers and machines than we have ever seen.

Rather than Building Information Modeling (BIM), we are going to see Building Information Optimization. Rather than manually drawing walls, doors, and columns for what we think is a good design, we will feed the computer "rules" instructing it to give us a building's optimal footprint, structural load capacity, and thermal performance. Things that took months will be done in a day. What does this mean for you? How do you play a part in these changing processes?

Where Are We Now

Most firms currently using BIM software are focused on gathering data. We design buildings manually, enter data manually, and then print data manually. This system works for the most part; however, it's not very efficient. By the way, most firms are not even executing this process very well. Most firms are using their BIM software like it's a CAD program.

In his book, *Rise of the Robots: Technology and the Threat of a Jobless Future*, Martin Ford discusses how software algorithms and robots will be replacing lower paying jobs such as fast food attendants as well as higher paying jobs such as writers and legal professionals. What patterns are you seeing in your own industry? What place might robots and algorithms eventually have in the office and in the field?

The movie *I, Robot* raises the question, "Can a robot write a symphony? Can a robot turn a canvas into a beautiful masterpiece?" In a Slate.com article, Chris Wilson states, "Cope has been writing software to help him compose music for 30 years, and he long ago reached the point where most people can't tell the difference between real Bach and the Bach-like compositions his computer can produce. Audiences have been moved to tears by melodies created by algorithms."

Pindar Van Arman, a technology artist and software engineer, has built a robot that can paint art. Van Arman, who is an avid painter himself, first built the robot as an assistant for his personal projects. Now the robot can make beautiful portraits and landscapes, either with the assistance of a human or entirely on its own.

Here's another question for you: Can an algorithm design a building? Can a robot construct a structure? If a tool doesn't exist or if there is a limitation in a program, we now can create our own tools. This capability has existed with things like Lisp routines in AutoCAD, and Dynamo for Revit. If you haven't jumped on the Dynamo bandwagon yet, you need to.

Static Modeling Versus Parametricism and Algorithmic Thinking

How does design happen at your office? Is the design typically modeled in a static design software like Sketchup? Of course the nice thing about conceptual modeling software is that you don't have to think as much about assemblies, materiality, etc.

What if we could make multiple design iterations in a conceptual tool without having to remodel our buildings every time there was a change? The most obvious advantage is the efficiency of not having to remodel over and over again. We can create multiple iterations very efficiently.

FormIt is another conceptual modeling tool. One nice advantage about FormIt is the ability to plug and play with Dynamo (pun intended). Below is a building someone on our team modeled using FormIt.

In the future, rather than gathering data and reporting on that data, we will use data to inform our designs. We can use Parametricism plus BIM to help us problem solve. One of the challenges I had with this specific design was to rationalize the radius such that the panels would divide evenly and stay planar for the fabricator. The way I problem solved this was thinking rational form=rational panels. Using data and math I was able to achieve this goal; however, the family was rigid and not intuitive to edit.

- # BIM Tools and Parametric modeling

The construction industry has changed significantly over the last 20 years. Digitalization is driving new innovations that are completely changing the way projects are designed, built, managed, and operated. The objective of CAD tools in the 1980s was fundamentally different compared to today: originally, CAD was a digital replacement for the drawing board, whereas today designers expect an efficient digital design process that enables innovative and complex designs. Parametric BIM modeling has evolved to meet this need, providing flexible tools that allow unlimited creativity during design.

What Is Parametric BIM Modeling?

Information is linked via algorithms in a digital parametric structured model so that when a change is made, components are updated automatically in line with specified parameters. Parametrics is a method that not only focuses on an individual result, such as with traditional CAD design, but rather describes the process of design. This process can be used to describe and automatically derive many different design variants. Today, parametric methods are used in many different applications like bionic construction, lightweight construction, modular construction, and infrastructure construction.

How Does Parametric BIM Modeling Increase Efficiency?

With parametrics, the individual architect becomes a designer of information chains, whose relationships he can define. If changes are made to the framework conditions, the components of a design are automatically updated using parametric BIM modeling. This removes human error and significantly reduces the time taken for updating designs compared to making manual design changes. As drawings are derived from the BIM model, layouts can be regenerated quickly and easily with every change.

How Does Parametric BIM Modeling Increase Design Flexibility?

The understanding of parametric design approaches and automatic production processes advances the capabilities of the designer and thus pushes the limits of the achievable complexity of components and designs. With the connection between the parametric model and BIM, it's also possible to integrate geometrically complex designs into the BIM process. And developing new construction methods – previously reserved for pioneers like Antoni Gaudi – has now become a flourishing field of research using parametric and digital production.

For example, when parametric modeling was first in use, organic, flowing forms made up of a variety of individual components were typical of designs created using parametric modeling. The freeform landmark buildings of several well-known architects are good examples of what can be achieved with parametric design. As the approach of parametrics has been refined, other aspects have been integrated, such as optimizing material or energy utilization, automating production, or nanalyzing the life cycle cost of a building during the design phase.

The concept of BIM has existed since the 1970s. The first software tools developed for modelling buildings emerged in the late 1970s and early 1980s, and included workstation products such as Chuck Eastman's Building Description System[1] and GLIDE, RUCAPS, Sonata, Reflex and Gable 4D Series.[2][3] The early applications, and the hardware needed to run them, were expensive, which limited widespread adoption.

The term 'building model' (in the sense of BIM as used today) was first used in papers in the mid-1980s: in a 1985 paper by Simon Ruffle eventually published in 1986,[4] and later in a 1986 paper by Robert Aish[5] - then at GMW Computers Ltd, developer of RUCAPS software - referring to the software's use at London's Heathrow Airport.[6] The term 'Building Information Model' first appeared in a 1992 paper by G.A. van Nederveen and F. P. Tolman.[7]

However, the terms 'Building Information Model' and 'Building Information Modeling' (including the acronym "BIM") did not become popularly used until some 10 years later. In 2002, Autodesk released a white paper entitled "Building Information Modeling,"[8] and other software vendors also started to assert their involvement in the field.[9] By hosting contributions from Autodesk, Bentley Systems and Graphisoft, plus other industry observers, in 2003,[10] Jerry Laiserin helped popularize and standardize the term as a common name for the digital representation of the building process.[11] Facilitating exchange and interoperability of information in digital format had previously been offered under differing terminology by Graphisoft as "Virtual Building", Bentley Systems as "Integrated Project Models", and by Autodesk or Vectorworks as "Building Information Modeling".

The pioneering role of applications such as RUCAPS, Sonata and Reflex has been recognized by Laiserin[12] as well as the UK's Royal Academy of Engineering.[13] Due to the complexity of gathering all the relevant information when working with BIM, some companies have developed software designed specifically to work in a BIM framework. These applications differ from architectural drafting tools such as AutoCAD by allowing the addition of further information (time, cost, manufacturers' details, sustainability, and maintenance information, etc.) to the building model.

As Graphisoft had been developing such solutions for longer than its competitors, Laiserin regarded its ArchiCAD application as then "one of the most mature BIM solutions on the market."[14] Following its launch in 1987, ArchiCAD became regarded by some as the first implementation of BIM,[15][16] as it was the first CAD product on a personal computer able to create both 2D and 3D geometry, as well as the first commercial BIM product for personal computers.[15][17][18] However, ArchiCAD founder Gábor Bojár has acknowledged to Jonathan Ingram in an open letter, that Sonata "was more advanced in 1986 than ArchiCAD at that time", adding that it "surpassed already the matured definition of 'BIM' specified only about one and a half decade later".[19]

Interoperability and BIM standards

As some BIM software developers have created proprietary data structures in their software, data and files created by one vendor's applications may not work in other vendor solutions. To achieve interoperability between applications, neutral, non-proprietary or open standards for sharing BIM data among different software applications have been developed.

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Poor software interoperability has long been regarded as an obstacle to industry efficiency in general and to BIM adoption in particular. In August 2004 a US National Institute

• History of Building Modeling Technology

- **Visualizing the Model**

- From the roots of the SAGE graphical interface and Ivan Sutherland's Sketchpad program in 1963, solid modeling programs began to appear building on developments in the computational representation of geometry. The two main methods of displaying and recording shape information that began to appear in the 1970s and 1980s were constructive solid geometry (CSG) and boundary representation (brep). The CSG system uses a series of primitive shapes that can be either solids or voids, so that the shapes can combine and intersect, subtract or combine to create the appearance of more complex shapes. This development is especially important in representing architecture as penetrations and subtractions are common procedures in design, (windows, doors).
  The process of design requires a visceral connection to the medium that the designer is working in. This posed another challenge as architects required a way to tell the computer what to do that was less tedious than the punch cards that were used on early computers. The development of light pens, head-mounted displays and various contraptions in the early days of human-computer interaction (HCI) are well documented elsewhere. A rigorous history of HCI from an architectural perspective can be found in Nicholas DeMonchaux's book, Spacesuit: Fashioning Apollo. The text carves a narrative of the precursors to BIM and CAD technology as they were entwined in the Space Race and Cold War.
- **Database Building Design**
- Seeing buildings through the lens of the database contributed to the breakdown of architecture into its constituent components, necessitating a literal taxonomy of a buildings constituent parts. One of the first projects to successfully create a building database was the Building Description System (BDS) which was the first software to describe individual library elements which can be retrieved and added to a model. This program uses a graphical user interface, orthographic and perspective views and a sortable database that allows the user to retrieve information categorically by attributes including material type and supplier. The project was designed by Charles Eastman who was trained as an architect at Berkeley and went on to work in computer science at Carnegie Melon Uniersity. Eastman continues as expert in BIM technology and Professor at the Georgia Tech School of Architecture.
- Eastman claims that drawings for construction are inefficient and cause redundancies of one object that is represented at several scales. He also criticizes hardcopy drawings for their tendency to decay over time and fail to represent the building as renovations occur and drawings are not updated. In a moment of prophecy, the notion of automated model review emerges to "check for design regularity" in a 1974 paper.
- Eastman concluded that BDS would reduce the cost of design, through 'drafting and analysis efficiencies' by more than fifty percent. Eastman's project was funded by DARPA, the Advanced Research Projects Agency and was written before the age of personal computers, on a PDP-10 computer. Very few architects were ever able to work on the BDS system and its unclear whether any projects were realized using the software. BDS was an experiment that would identify some of the most fundamental problems to be tackled in architectural design over the next fifty years. Eastman's next project, GLIDE (Graphical Language for Interactive Design) created in 1977 at CMU, exhibited most of the characteristics of a modern BIM platform.
- In the early 1980′s there were several systems developed in England that gained traction and were applied to constructed projects. These include GDS, EdCAAD, Cedar, RUCAPS, Sonata and Reflex. The RUCAPS software System developed by

GMW Computers in 1986 was the first program to use the concept of temporal phasing of construction processes and was used to assist in the phased construction of Heathrow Airport's Terminal three (Laiserin – History of BIM). The founding of the Center for Integrated Facility Engineering (CIFE) at Stanford in 1988 by Paul Teicholz marks another landmark in the development of BIM as this created a wellspring of PhD students and industry collaborations to further the development of 'four-dimensional' building models with time attributes for construction. This marks an important point where two trends in the development of BIM technology would split and develop over the next two decades. On one side, the development of specialized tools for multiple disciplines to serve the construction industry and improve efficiency in construction. On the other side is the treatment of the BIM model as a prototype that could be tested and simulated against performance criteria.

- A later but prominent example of a simulation tool that gave feedback and 'suggested' solutions based on a model is the Building Design Advisor, developed at Lawrence Berkeley National Lab beginning in 1993. This software utilizes an object model of a building and its context to perform simulations. This program was one of the first to integrate graphical analysis and simulations to provide information about how the project might perform given alternative conditions regarding the projects orientation, geometry, material properties and building systems. The program also includes basic optimization assistants to make decisions based on a range of criteria which are stored in sets called 'Solutions'.
- **irtual Building**

- While the developments were happening rapidly in the United States, the Soviet Block had two programming geniuses who would end up defining the BIM market as it is known today. Leonid Raiz and Gábor Bojár would go on to be the respective co-founder and founder of Revit and ArchiCAD. ArchiCAD developed in 1982 in Budapest, Hungary by Gábor Bojár, a physicist who rebelled against the communist government and began a private company. Gábor wrote the initial lines of code by pawning his wife's jewelry and smuggling Apple Computers through the Iron Curtain (Story). Using similar technology as the Building Description System, the software Radar CH was released in 1984 for the Apple Lisa Operating System. This later became ArchiCAD, which makes ArchiCAD the first BIM software that was made available on a personal computer.
- The software was slow to start as Bojár had to struggle with a unfriendly business climate and the limitations of personal computer software, so ArchiCAD was not used on large scale projects until much later. ArchiCAD has made substantial gains in user base from 2007-2011, mainly as a tool for developing residential and small commercial projects in Europe. Recent improvements have made ArchiCAD a major player in the market though fundamental issues such as a lack of a phasing component and a complicated (but flexible) programming environment for its family components using GDL (Geometric Description Language) To date, Graphisoft claims that more than 1,000,000 projects worldwide have been designed using ArchiCAD.

- Not long after Graphisoft began to sell the first seats of Radar CH, Parametric Technology Corporation (PTC) was founded in 1985 and released the first version of Pro/ENGINEER in 1988. This is a mechanical CAD program that is utilizes a constraint based parametric modeling engine. Equipped with the knowledge of working on Pro/ENGINEER, Irwin Jungreis and Leonid Raiz split from PTC and started their own software company called Charles River Software in Cambridge, MA.

- The two wanted to create an architectural version of the software that could handle more complex projects than ArchiCAD. They hired David Conant as their first employee, who is a trained architect and designed the initial interface which lasted for nine releases. By 2000 the company had developed a program called 'Revit', a made up word that is meant to imply revision and speed, which was written in C++ and utilized a parametric change engine, made possible through object oriented programming. In 2002, Autodesk purchased the company and began to heavily promote the software in competition with its own object-based software 'Architectural Desktop'.

- Revit revolutionized the world of Building Information Modeling by creating a platform that utilized a visual programming environment for creating parametric families and allowing for a time attribute to be added to a component to allow a 'fourth-dimension' of time to be associated with the building model. This enables contractors to generate construction schedules based on the BIM models and simulate the construction process. One of the earliest projects to use Revit for design and construction scheduling was the Freedom Tower project in Manhattan. This project was completed in a series of separated but linked BIM models which were tied to schedules to provide real-time cost estimation and material quantities. Though the construction schedule of the Freedom Tower has been racked with political issues, improvements in coordination and efficiency on the construction site catalyzed the development of integrated software that could be used to view and interact with architects, engineers and contractors models in overlay simultaneously.
- **Towards a Collaborative Architecture**

- There has been a trend towards the compositing of architectural files with those of engineers who create the systems to support them which has become more prevalent within the past seven years as Autodesk has released versions of Revit specifically for Structural and Mechanical engineers. This increased collaboration has had impacts on the larger industry including a movement away from design-bid-build contracts towards integrated project delivery where many disciplines typically work on a mutually accessible set of BIM models that are updated in varying degrees of frequency. A central file takes an object and applies an attribute of ownership so that a user who is working on a given project can view all objects but can only change those that they have checked out of a 'workset'. This feature released in Revit 6 in 2004, enables large teams of architects and engineers to work on one integrated model, a form of collaborative software. There are now several firms working towards visualization of BIM models in the field using augmented reality.
- A broad variety of programs used by architects and engineers makes collaboration difficult. Varying file formats lose fidelity as they move across platforms, especially BIM models as the information is hierarchical and specific. To combat this inefficiency the International Foundation Class (IFC) file format was developed in 1995 and has continued to adapt to allow the exchange of data from one BIM program to another. This effort has been augmented by the development of viewing software such as Navisworks which is solely designed to coordinate across varying file formats. Navisworks allows for data collection, construction simulation and clash detection and is used by most major contractors in the US today.

- Following in the footsteps of the Building Design Advisor, simulation programs such as Ecotect, Energy Plus, IES and Green Building Studio allow the BIM model to be imported directly and results to be gathered from simulations. In some cases there are simulations that are built directly into the base software, this method of visualization for design iteration has been introduced to Autodesk's Vasari, a stand alone beta program similar to the Revit Conceptual Modeling Environment where solar studies and insolation levels can be calculated using weather data similar to the Ecotect package. Autodesk, through their growth and acquisition of a broad variety of software related to BIM have contributed to the expansion of what is possible from analysis of a model. In late November 2012, the development of formit, an application that allows the conceptual beginnings of a BIM model to be started on a mobile device is a leap for the company.

- **Contemporary Practice and Design Academics**

- Some have taken a negative stance on BIM and parametrics as they assume so much about the design process and limit any work produced to the user's knowledge of the program. This can enable a novice designer who has learned how to perform basic commands to become an incredibly prolific producer while a highly educated and experienced architect can be crippled from inexperience with a programs interface or underlying concepts. This creates a potential for a generational break line that becomes more harsh as a new technology gains market parity.

- Some BIM platforms that have a small market share but have made big impacts on the world of design include Generative Components (GC), developed by Bentley Systems in 2003. The GC system is focused on parametric flexibility and sculpting geometry and supports NURBS surfaces. The interface hinges on a node-based scripting environment that is similar to Grasshopper to generate forms. Digital Project is a similar program was developed by Gehry Technologies around 2006 based on CATIA, a design program (and one of the first CAD programs) that was developed as an in house project by Dessault systems, a French airplane manufacturer. These two platforms have spawned something of a revolution in design as the power to iterate and transform has resulted in especially complex and provocative architectural forms.

- Patrick Schumacher has coined the movement of parametric building models in architecture, specifically those which allow for NURBS surfaces and scripting environments as 'parametricism' in his 2008 'Parametricist Manifesto'.
- "The current stage of advancement within parametricism relates as much to the continuous advancement of the attendant computational design technologies as it is due to the designer's realization of the unique formal and organizational opportunities that are afforded. Parametricism can only exist via sophisticated parametric techniques. Finally, computationally advanced design techniques like scripting (in Mel-script or Rhino-script) and parametric modeling (with tools like GC or DP) are becoming a pervasive reality. Today it is impossible to compete within the contemporary avant-garde scene without mastering these techniques."

- Since these techniques have become increasingly complex there has become a component of architectural schools which is specified to train in specific software. A student with knowledge of only one type of software platform may well be trained to design according to the biases of the programs that they are using to represent their ideas. Software performs useful tasks by breaking down a procedure into a set of actions that have been explicitly designed by a programmer. The programmer takes an idea of what is commonsense (Sack 14) and simulates a workflow using tools available to them to create an idealized goal. In the case of BIM tools, the building is represented as components including walls, roofs, floors, windows, columns, etc.

These components have pre-defined rules or constraints which help them perform their respective tasks.

- BIM platforms typically represent walls as objects with layers, these layers are defined in terms of the depth and height of a wall and are extruded along the length of a line. The program then has the ability to calculate the volume of material contained within the wall assembly and to create wall sections and details easily. This type of workflow is based on the existing building stock and common industry standards and therefore a project which is produced in a BIM platform which emphasizes these tools is likely to reinforce existing paradigms rather than develop new ones. Additionally, the programmers who worked on the early BIM platforms often did not have a background in architecture but employed hybrid architect/programmers who contributed to the development of the programs. One notable exception I have found to this is the work of Charles Eastman who received a Masters of Architecture from Berkeley before working on the Building Description System. The roots of the major BIM platforms that are in use today have been developed by programmers with the peripheral input of hybrid programmer/architects and a global user base who contributes to the development of the software via 'wish lists' or online forums where grievances can be aired about a product workflow. The grievances typically result in new features and build upon the existing interface.

- Though the general concept and technology behind BIM is approaching its thirtieth anniversary, the industry has only begun to realize the potential benefits of Building Information Models. As we reach a point where a majority of buildings are being crafted digitally, an existing building marketplace where building materials and structural components can be bought and sold locally will emerge. Sustainable design practices reinforce an attitude of designing for disassembly and a marketplace of these parts is essential. Trends in Human Computer Interaction, Augmented Reality, Cloud Computing, Generative Design and Virtual Design and Construction continue to rapidly influence the development of BIM. Looking back at the past it is easier to realize that the present moment is an exciting time for designers and programmers in this evolving industry.

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● Varied Capabilities of Parametric Modelers

Parametric is a term used to describe a dimension's ability to change the shape of model geometry as soon as the dimension value is modified.

Feature-based is a term used to describe the various components of a model. For example, a part can consists of various types of features such as holes, grooves, fillets, and chamfers. A 'feature' is the basic unit of a parametric solid model.

Parametric modelling uses the computer to design objects or systems that model component attributes with real world behaviour. Parametric models use feature-based, solid and surface modelling design tools to manipulate the system attributes. One of the most important features of parametric modelling is that attributes that are interlinked automatically change their features. In other words, parametric modelling allows the designer to define entire classes of shapes, not just specific instances. Before the advent of parametrics, editing the shape was not an easy task for designers. For example, to modify a 3D solid, the designer had to change the length, the breadth and the height. However, with parametric modelling, the designer need only alter one parameter; the other two parameters get adjusted automatically. So, parametric models focus on the steps in creating a shape and parameterize them. This benefits product design engineering services providers a lot.

The Parametric Modelling Process

Parametric models are built from a set of mathematical equations. For parametric models to have any legitimacy, they must be based on real project information. It is the modernity of the information examination techniques and the breadth of the hidden undertaking information which decides the viability of a modelling solution.

There are two popular parametric representation models:

Constructive Solid Geometry (CSG)

CSG defines a model in terms of combining basic (primitive) and generated (using extrusion and sweeping operation) solid shapes. It uses Boolean operations to construct a model. CSG is a combination of 3D solid primitves (for example a cylinder, cone, prism, rectangle or sphere) that are then manipulated using simple Boolean operations.

Boundary Representation (BR)

In BR, a solid model is formed by defining the surfaces that form its spatial boundaries (points, edges, etc.) The object is then made by joining these spatial points. Many Finite Element Method (FEM) programs use this method, as it allows the interior meshing of the volume to be more easily controlled.

Advantages

These are the benefits offered by 3D parametric modelling over traditional 2D drawings:

- Capability to produce flexible designs
- 3D solid models offer a vast range of ways to view the model
- Better product visualization, as you can begin with simple objects with minimal details
- Better integration with downstream applications and reduced engineering cycle time
- Existing design data can be reused to create new designs
- Quick design turnaround, increasing efficiency

Parametric Modelling Tools

There are many software choices available in the market today for parametric modelling. On a broad level, this software can be categorized as:

- Small scale use
- Large scale use
- Industry specific modelling

Of the three, the last category (viz. industry specific parametric software) has gained in popularity. A few of the leading industry software is:

SolidWorks

Introduced in 1995 as a low-cost competitor to the other parametric modeling software products, SolidWorks was purchased in 1997 by Dassault Systemes. It is primarily used in mechanical design applications and has a strong following in the plastics industry.

CATIA

Dassault Systemes created CATIA in France in the late 1970s. This sophisticated software is widely used in the aeronautic, automotive, and shipbuilding industries.

PTC

Creo Parametric is the standard in 3D CAD software. It provides the broadest range of powerful yet flexible 3D CAD capabilities to accelerate the design of parts and assemblies.

- # Overview of the Major BIM Model

5.1 Brief history and overview

What is BIM? Building information modeling (BIM) is one of the more promising developments in the architecture, engineering, and construction fields. It is changing the way contractors and engineers do business, but its application is still relatively new and there is much to learn. One way to learn is from observing how other businesses are using BIM and their trials and tribulations along the way. BIM was introduced over a decade ago mainly to distinguish the information-rich architectural 3D modeling from the traditional 2D drawing. It is being acclaimed by its advocates as a lifesaver for complicated projects because of its ability to correct errors early in the design stage and accurately schedule construction.

Although over recent years, the term "building information modeling" or "BIM" has gained widespread popularity, it has failed to gain a consistent definition. According to Patrick Suermann, PE, a National Building Information Model Standard (NBIMS) testing team leader, "BIM is the virtual representation of the physical and functional characteristics of a facility from inception onward. As such, it serves as a shared information repository for collaboration throughout a facility's life cycle." The National Institute of Building Sciences (NIBS) sees it as "a digital representation of physical and functional characteristics of a facility…and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle, defined as existing from earliest conception to demolition." But generally speaking, BIM technology allows an accurate virtual model of a building to be constructed digitally. Completed computer-generated models contain accurate and well-defined geometry and pertinent data required to facilitate the construction, fabrication, and procurement activities necessary to realize the final building.

BIM consists mainly of 3D modeling concepts in addition to information database technology and interoperable software in a desktop computer environment that architects, engineers, and contractors can use to design a facility and simulate construction. This technology allows members of the project team to generate a virtual model of the structure and all of its systems in 3D and to be able to share that information with each other. Likewise, the drawings, specifications, and construction details are fundamental to the model, which includes attributes such as building geometry, spatial relationships, quantity characteristics of building components, and geographic information. These allow the project team to quickly identify design and construction issues and resolve them in a virtual environment well before the Construction Phase in the real world.

BIM is therefore primarily a process by which you generate and manage building data during a project's life cycle. It typically uses three-dimensional, real-time, dynamic building-modeling software to manage and increase productivity in building design and construction. The process produces the building information model, which encompasses all relevant data relating to building geometry, spatial relationships, geographic information, and quantities and properties of building components. Construction technology for the BIM process is continuing to improve with the passing of time as contractors, architects, engineers, and others continue to find new ways to improve the BIM process. One of the many significant advantages of using modern BIM design tools, as Chuck Eastman, director of Digital Building Laboratory**,** states, is:

[They now] define objects parametrically. That is, the objects are defined as parameters and relations to other objects, so that if a related object changes, this one will also. Parametric objects automatically re-build themselves according to the rules embedded in them. The rules may be simple, requiring a window to be wholly within a wall, and moving the window with the wall, or complex defining size ranges, and detailing, such as the physical connection between a steel beam and column.

But before one can give a precise definition of BIM, one must resolve the ambiguity over whether it is or is not fundamentally different from CAD or CADD. In the author's opinion, BIM is not CAD, nor is it intended to be. CAD is a replacement for pen and paper, a documentation tool, and CAD files are basic data consisting of elements that are lines, arcs, and circles—and sometimes surfaces and solids—that are purely graphical representations of building components. Moreover, early definitions asserting that BIM is basically a 3D model of a facility are incorrect and do not reflect the truth, nor do they adequately communicate the capabilities and potential of digital, object-based, interoperable building information modeling processes and tools and modern communications techniques.

BIM programs today are design applications in which the documentation flows from and is a derivative of the process, from schematic design to construction to facility management. Furthermore, with BIM technology, an accurate virtual model of a building can be constructed digitally, and when completed, the computer-generated model will contain all the relevant data and accurate geometry needed to support the construction, fabrication, and procurement activities required to execute the project. Ken Stowe, of AEC Division at Autodesk®, reaffirms this and comments:

The construction industry is in the early stages of an historic transformation: from a 2D environment to a model-based environment. The benefits are many and are enjoyed by various members of the project team. Some firms are leading in planning and directing the whole team in BIM participation, implementing best practices, and making a point of measuring those benefits. The savings can be in the millions of dollars. The project durations are being reduced by weeks or months.

It is sometimes difficult to determine who first coined the term “BIM.” Some claim Charles M. Eastman at Georgia Tech coined the term, the theory being based on a view that the term is basically the same as “building product model,” which Eastman has used extensively in his publications since the late 1970s. Others believe it was first coined by architect and Autodesk building industry strategist Phil Bernstein, FAIA, who reportedly used the actual term “building information modeling,” which was later accepted by Bentley Systems and others. (See Figure 5.1.) It is claimed that Graphisoft® produced the original BIM—in the original terminology “virtual building”—software, known as ArchiCAD. But many firms and organizations made contributions to BIM's continuing development.

For example, Skidmore, Owings & Merrill (SOM) is one such pioneering firm that made significant contributions to the development and use of BIM. Early on, SOM created a multipurpose, database-driven, modeling system known as AES, or architecture engineering system, and single-handedly pioneered its development. AES is regarded by some as the precursor to today's BIM tools. As noted at http://som.com/content.cfm/brief_history_4:

In the future, SOM envisions BIM as a vehicle for real-time performative design simulation and environmental analysis, enabled through new visual and tactile feedback systems. This will allow architects to focus on building performance that can truly be validated—obtaining and interpreting data as one simultaneously designs—and will encompass new modes of collaboration. SOM envisions the architect/engineer in a pivotal role in this new virtual design and construction collaborative environment: as the conceiver of ideas and the manager of knowledge.

Dana (Deke) Smith, FAIA, executive director of the buildingSMART alliance™ who has been involved with the development of building information modeling since its inception, says: “One of the basic principles and metrics for BIM implementation is the ability to enter data one time and then use it many times throughout the life of the project.” Smith identifies the following 10 principles of BIM:

1. Coordinate and plan with all parties before you start.
2. Ensure all parties have a life-cycle view—involve them early and often.
3. Build the model then build to the model.
4. Detailed data can be summarized (the reverse is not possible).
5. Enter data one time, then improve and refine over life.
6. Build data sustainment into business processes—keep data alive.
7. Use information assurance and metadata to build trust—know data sources and users.
8. Contract for data—good contracts make good projects.
9. Ensure that data are externally accessible yet protected.
10. Use international standards and cloud storage to ensure long-term accessibility.

Smith believes the following:

We are still all too often slaves to the stovepipes that have been our industry's tradition, where information is collected for a specific instance and then not reused by others. There are currently many reasons for this: perceived intellectual property concerns, perceived liability issues, organizations pushing their own agenda, proprietary approaches, and simply not knowing that someone already entered the information because of poor ability to collaborate.

One group taking this challenge head-on is buildingSMART International. buildingSMART International is a coalition of more than 50 countries worldwide who are focused on implementing an open-standard, BIM approach to interoperability of information for building construction and facility maintenance. The North American chapter of this group is the buildingSMART alliance. While it is our belief that the final goal will be an international, standards-based, information exchange, the primary goal of interoperability remains at the foundation of this effort, using whatever format is universally easiest to use at the time.

Today, we have several organizations with initiatives under way to develop a national BIM standard. In 2007, the first version of this standard (NBIMS Version 1) was passed, but it has failed to take hold in the architecture, engineering, and construction (AEC) community mostly because of its reliance on the IFC (Industry Foundation Class) file format for 3D modeling. After several years, the National Institute of Building Sciences' buildingSMART alliance developed version 2 of the National BIM Standard–United States, which is a significant improvement on version 1. The United Kingdom has also come out with its own AEC (UK) BIM standards.

Multiple federal agencies have implemented BIM initiatives, from the GSA and the Army Corps of Engineers to the U.S. Coast Guard and Sandia National Laboratories. Finith Jernigan, FAIA, president of Design Atlantic, says, "To prosper in today's fast changing and unpredictable markets, you need new ways of doing business more effectively." And although BIM is not a technology, it does require appropriate technology to be effectively implemented.

BIM

Eur Ing Albert Lester CEng, FICE, FIMechE, FIStructE, FAPM, in Project Management, Planning and Control (Sixth Edition), 2014

What Is BIM?

So what is BIM? It could simply be defined as rapidly evolving collaboration tools that facilitate integrated design and construction management. The importance of 'I' in BIM should never be underestimated, as this becomes a project or support for the company's enterprise framework and not just a means for 'building models'. This information means that more work is done earlier in the project to support green issue concepts, as less waste saves both materials and energy.

BIM enables multidimensional models including space constraints, time, costs, materials, design and manufacturing information, finishes, etc., to be created and even allows the support for information-based real-time collaboration. This information can be used to drive other recent technologies including city-sized models, augmented reality equipment used on site, radio-frequency identification (RFID) tags to track components from manufacture to site, and even the use of 3D printers.

It may be useful to consider the players who would want to have access to the BIM models. Not limiting the list they could include the clients, local authorities, architects, engineers (structural, civil, and MEP), main contractors, steelwork and concrete subcontractors, formwork contractors, and all site personnel. Until recent years BIM was only available as a solution for architects, engineers, and steelwork contractors, leaving everyone else just to work with 2D drawings that may be industry-specific but not totally readable without knowledge of that environment.

Various references have been made to the architects' BIM model or the structural BIM. However, they really are the same, as the boundaries between their models and their content are lessening all of the time. Architects' BIM models will include structural member sizes, but the models that they produce do not normally need to include the material grades, reactions, and finishes. Where the model is produced by the steelwork contractor, it will include at least the manufacturing details and all the information necessary to order, fabricate, deliver, and erect the members. The MEP contractor could also define the site fixings on his versions of the model, as the contractor will want to know when the member will be on site, where it will be fixed or poured, and how much the item costs. The client's view of the same member would be for control and for possible site maintenance. For this reason various models are created in the 'best-of-breed' authoring applications and shared with other design-team members as reference models, which are normally in the form of Industry Foundation Class (IFC) files for all structures except the plant and offshore markets, where CIMsteel Integration Standards (cis/2) and dgn format files are the dominant interoperability formats.

It is so much easier to work with a BIM model and to explore the building in 3D with rich information, than looking at hundreds of drawings and having to understand the industry drawing conversions. Now users can simply click on an object and obtain all the information that they require either through the native object, if in the authoring application, or through the reference model or even from a viewer or collaboration tool.

Sustainable Built Environment & Sustainable Manufacturing

Llewellyn Tang, ... Polina Trofimova, in Encyclopedia of Sustainable Technologies, 2017

Interoperability between BIM-based design and energy simulation tools

BIM software that enables 3D modeling and information management is a significant part of BIM. The commonly used sustainability analysis software involves Autodesk Green Building Studio, Energy 10, HEED, Design Builder, Autodesk Ecotect, eQUEST, Integrated Environmental Solutions, Virtual Environment (IES-VE), and EnergyPlus. However, there is a challenge in the exchange of data between building design tools and sustainability analysis tools. In other words, the sustainability analysis tools lack the compatibility with BIM-based design software.

Interoperability between BIM-based design and energy simulation tools is being researched in recent years. For instance, Jeong et al. (2015) developed an automated framework utilizing BIM application programming interface and Modelica-based BEM which could simulate and visualize energy analysis results back inside the BIM software Revit to obtain a direct feedback. Welle et al. (2011) and Ahn et al. (2014) proposed IFC-based tools for automated thermal simulation with EnergyPlus through input data files containing geometry, thermal space boundaries, and material information from the BIM model, aiming to improve the accuracy and modeling time of the BEM models. Whereas Cemesova et al. (2015) created an IFC-based tool to combine BIM and Passive House Planning Package design tool for energy performance and decision making for PassivHaus certifications.

In a word, the application of BIM in building sustainability analysis may optimize the building performance. Besides, it may improve the efficiency of rating process using the results generated by the BIM tools directly. Meanwhile, studies on the interoperability between BIM-based design and energy simulation tools may assist in further BIM application for optimizing the building performance.

Building Information Modeling (BIM)

Sam Kubba PH.D., LEED AP, in Handbook of Green Building Design and Construction (Second Edition), 2017

5.5.2 AIA Document E202

Because BIM is a relatively new technology, there were some legal challenges and other issues that necessitated clarification. To help clear up these legal issues with BIM, the AIA recently released document E202, which lays out standard procedures and responsibilities for BIM models, but most importantly, it serves as a standard contract for projects using BIM. This document also establishes certain rules and regulations such as who owns the model, how it is used, and the party responsible for each model element. Because of the unique nature of each project, Document E202 cannot give a blanket declaration of each; rather it lays out a legally binding frame work of rules and then allows for adaption to each unique project (AIA, 2008, p. 1).

AIA Document E202 has been a huge boon to BIM-based contracts. People all across the building industries recognize AIA and have embraced their efforts in simplifying the complex legal environment around BIM. Because BIM is in many respects still new, many of those dealing in construction law simply do not know how to work with BIM. Document E202 created a standard BIM-based contract that addresses many of the legal issues and challenges faced when using BIM.

Design and Analysis of Complex Structures

Feng Fu, in Design and Analysis of Tall and Complex Structures, 2018

6.5 Building Information Modeling

British Standards Institute gives an accurate definition of BIM, the definition is: "the process of generating and managing information about a building during its entire life. BIM is a suite of technologies and processes that integrate to form the 'system' at the heart of which is a component-based 3D representation of each building element; this supersedes traditional design tools currently in use."

In other words, BIM is a 3D digital modeling method for modeling, controlling a building project. Each design team member creates and maintains its own BIM model as part of a "central model." The BIM models should also have the capacity of clash detection in a central model by different contributors.

Government construction strategy [15] has started to promote the adoption of BIM since 2011. Therefore, BIM will dominant the construction industry development in the next several decades, changing the way of the interaction between different disciplines of the construction industry. In this section, the BIM will be discussed in detail.

6.5.1 Introduction

BIM allows users to build a model using software such as Revit. The model contains all the project information, including drawings and specifications. All different stakeholders have access to the central model made in Revit, enabling project participants from all disciplines such as architects, facility managers, M & E Engineers, and structural engineers to coordinate their work. BIM integrates designs from initial design to construction and until the project finishes. Using a program such as Revit, updates of drawing can be done automatically to reflect each discipline's input, enabling integrated management of information of building components.

The use of the BIM increases the productivity of the design activities, consequently resulting in efficient building designs which, in turn, saves the material cost. It can also result in shorter construction times and a safer construction process. As systems are increasingly digitized, BIM is seen as fundamental to the development of future smarter cities.

6.5.2 Standard Methods and Procedures' Protocols

When using BIM, a standard protocol is important for the whole BIM process. The protocol should consist of document naming, data file naming, and CAD layer naming, origin, scale, orientation of structure model, etc. Standard procedures should also be defined between different disciplines. All of these are required by effective data sharing through a common data environment.

It should make sure to

- unify layer naming and file naming
- collect, manage, and disseminate data effectively in the required formats
- ensures compliance to agreed standards
- able to aid design managers in the timely delivery of the construction schedule
- for members of the supply chain not using BIM (such as small contractors) to find a way to integrate them into the process
- set up the approval process and the design and sign-off processes to improve the project management and documentation control

6.5.3 Design Liability and Legal Issue of BIM

When BIM becomes widely used, some legal issues emerged such as

- obligations to create/contribute to BIM models in agreed forms and deadlines
- liability for each team member
- how to insure the work on BIM models by an insurance company
- ownership of BIM models and data and licensing for agreed purposes
- legal status of BIM approach to collaborative working

The construction industry council issued the first edition of “Building Information Modeling (BIM) protocol” [16] in 2013. The protocol covers below the main issues: contract, intellectual property, electronic data exchange, change management, liability for the use of models.

The primary objective of the protocol is to enable the production of BIMs at defined stages of a project. It requires the employer to appoint a party to undertake an information management role such as an “information manager.” Another objective is to support the adoption of effective collaborative working practices in project teams, making an explicit contractual requirement under the protocol.

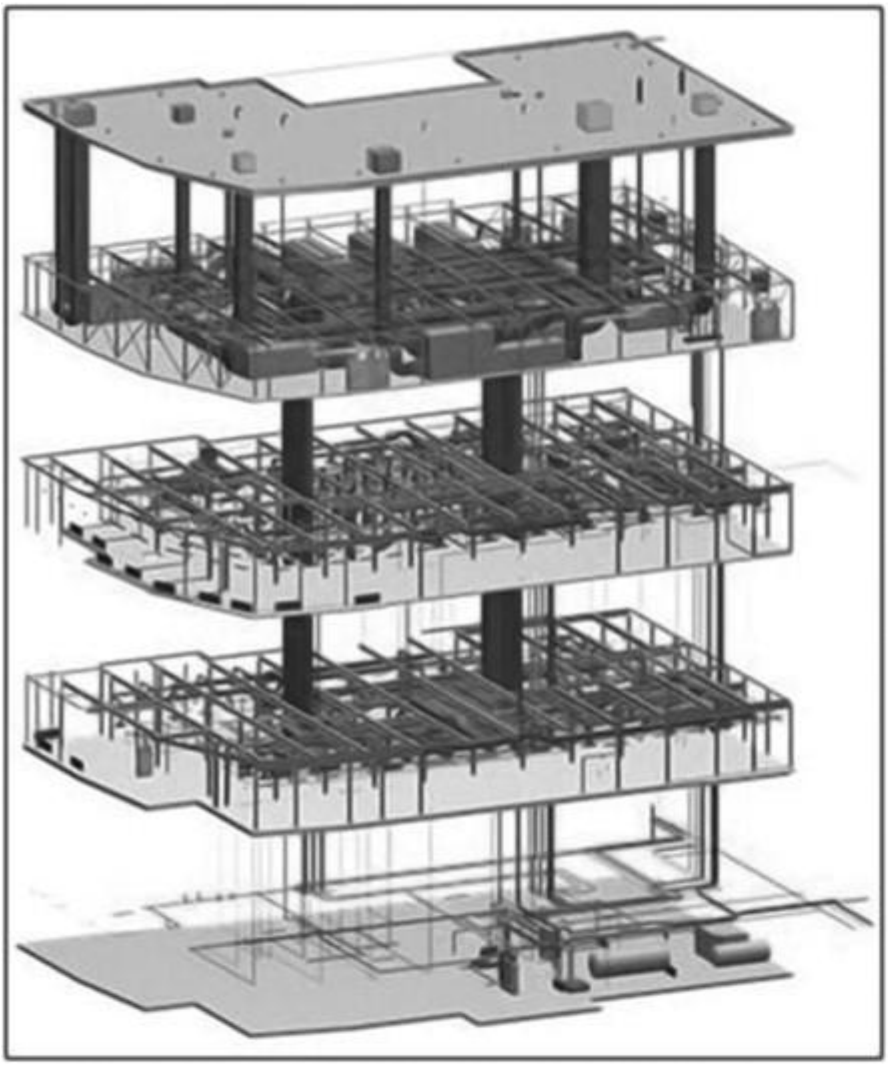
It is worth noting that it is required that all project team members are required to have a BIM protocol appended to their contracts. This will ensure that all parties producing and delivering models adopt any common standards or ways of working described in the protocol and that all parties using the models have a clear right to do so.

Design, Construction, and Renovations

James Sinopoli, in Smart Building Systems for Architects, Owners and Builders, 2010

Building Information Model

Building information modeling (BIM) is the future of building design and construction. BIM is a 3-D, object-oriented, CAD approach for architects and engineers. While the number of architects and building designers using BIM is modest the number will continue to increase. One of the most valuable functions of BIM is its ability to improve the coordination between multiple design disciplines, thus reducing errors. BIM has the potential to respond to an owner's need for predictable costs, quality, and on-time delivery. (See Figure 13.4.)



Sign in to download full-size image

Figure 13.4. Typical building information model.

The American Institute of Architects have called BIM a "model-based technology linked with a database of project information." It can store complete information about a building in a digital format including things like the quantities and properties of building components. It covers geospatial information and relationships regarding a building, and facilitates the digital exchange and interoperability of the data.

BIM uses the Industry Foundation Classes (IFC) for exchanging information about a building project among different CAD packages. XML, an Internet language, which allows raw data to be reliably shared over the Web, will also be used in BIM implementations. BIM has the potential to be the vehicle or depository for use by the design team, the contractors, and owner, with each party having the capability to add their own data and information to the model. The National BIM Standard (NBIMS) is being developed and major vendors have endorsed and supported the effort.

BIM has major benefits. One is the capability for BIM tools to detect "collisions," that is, design features that are incompatible and in conflict. For instance, assume that a water pipe designed by the mechanical engineer would be installed in a way that it goes through a steel beam designed by the structural engineer. BIM allows the design and construction teams to identify such collisions electronically rather than discover the collision at the construction site. The result is time savings and reduced construction change orders and related costs.

Probably more important is BIM's capability to provide the location, quantities, and properties of building components in product objects. Included in this information can be all details of components, such as manufacturer, model, warranty, preventive maintenance, and so on. This information is valuable in the operation and maintenance of the building.

BIM is becoming more widely accepted for use in facility management. Starting in 2007, the U.S. General Services Administration (USGSA), under its National 3D-4D-BIM Program, requires spatial program information from BIMs for major projects receiving design funding. Four-dimensional (4D) models, which combine a 3D model with time, support the understanding of project phasing.

The American Institute of Architects (AIA) is modifying its contract documents to easily allow BIM, which is considered intellectual property, to make transfers from the architect to the facility manager, thus providing the facility manager with better data to manage a building.

The buildingSMART alliance, part of the U.S. National Institute of Building Sciences, provides useful tools to developers and users of BIM software and promotes the use of BIM. There are many important organizations that are a part of the buildingSMART alliance including the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE).

The use of BIM may soon replace the Computer-Aided Facility Management (CAFM) process for facility managers. Typically the facility manager scans paper floor plans or imports electronic CAD files for use within the CAFM application. The electronic floor plans are then used to create “polylines” to define an area and identify room numbers to name that area.

For a typical commercial building, this process can take weeks. Instead, BIM files can be moved from the BIM creation software to facility management BIM software. The user can import the BIM file into software, which would include the room boundaries, room areas, room numbers, and space descriptions from the BIM. It would then perform the same functions as the typical CAFM software would but without all the lost time from the creation of “polylines.”

In the not too distant future design and construction projects will require an information manager. This person or team will set the requirements for data management for the owner's project team, the design team, and construction contractors; manage the “supply chain” of data from design to construction to operations; and manage the integration of the data from the building and building systems into the owner's facility management and business systems. The drivers are economics, technology, increased functionality, and the overall value proposition.

- **Generating Systems**

- beam designed by the structural engineer. BIM allows the design and construction teams to identify such collisions electronically rather than discover the collision at the construction site. The result is time savings and reduced construction change orders and related costs.
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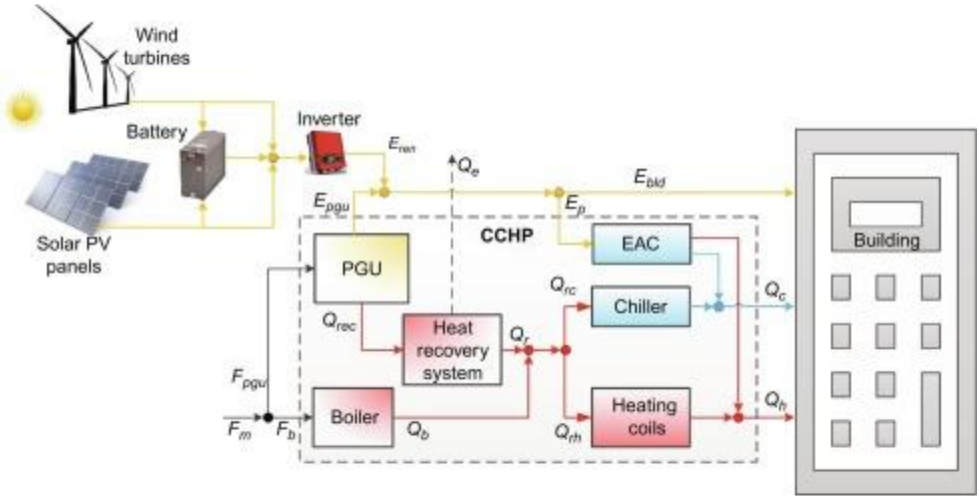
Decentralized power generation systems have the flexibility of diversifying power production sources combined with various energy storage systems, which bring enormous resilience in matching the power supply and demand at low cost. This option has been progressively deployed worldwide, particularly in islands and remote areas where the accessibility to the national grid is often unfeasible or expensive. The renewable sources that match this type of distributed power generation systems would be solar PV fields, wind farms, or a combination of them. The integration model for these renewable applications with CCHP systems is most likely to follow the EDM strategy where the priority is in maintaining the electrical load of the building/entity (Fig. 6). The DC electric power generated by solar PV, wind turbine, or a combination of them is converted to AC power by an inverter. Beforehand, the

5.1 Electric Energy Harvest

Decentralized power generation systems have the flexibility of diversifying power production sources combined with various energy storage systems, which bring enormous resilience in matching the power supply and demand at low cost. This option has been progressively deployed worldwide, particularly in islands and remote areas where the accessibility to the national grid is often unfeasible or expensive. The renewable sources that match this type of distributed power generation systems would be solar PV fields, wind farms, or a combination of them. The integration model for these renewable applications with CCHP systems is most likely to follow the EDM strategy where the priority is in maintaining the electrical load of the building/entity (Fig. 6). The DC electric power generated by solar PV, wind turbine, or a combination of them is converted to AC power by an inverter. Beforehand, the surplus/deficit power is regulated by using a set of batteries. The primary objective of the renewable energy sources + energy storage + the power generated by the local PGU is to maintain the electric load and also run an electric air conditioner to balance and adjust the cooling/heating load for the building. The exhaust heat recovered from the PGU is used in the adjacent chiller or heating coils, accordingly (Fig. 6).



Power generating systems are generally treated as heat engines to convert heat input into work, hence to produce electricity at a sustained rate. Heat input is supplied by burning fossil fuels (coal, oil and natural) and biomass, or processing nuclear fuel, or harvesting thermal energy from renewable energy sources. For example, in a conventional coal-fired power plant (the term power station is also used), the energy of coal is eventually converted into power. In general, conventional power stations comprise multiple generating units which are designed to operate at their nominal load when they function optimally.

There are a number of well-known power generating systems denoted as conventional, namely the spark ignition engine, compression-ignition engine, steam Rankine or organic Rankine power plant, combustion turbine power plant, combined cycle power station, nuclear power station, and hydroelectric power station. All these conventional power generating systems (CPGSs) primarily produce mechanical work which is transferred to subsequent systems in the form of shaft rotation. In vehicles, shaft power developed by engines is transferred to the traction system for propulsion. In stationary power plants or generators the shaft power developed by the prime mover is used to rotate an electrical generator which converts the rotational mechanical power to electrical power.

The key component of a CPGS is the prime mover or the organ that produces shaft power. Two types of prime movers are used in CPGSs: positive displacement machines (e.g., reciprocating engines) and turbomachines. Reciprocating machines generally consist of piston-and-cylinder assemblies where the pressure force of an expanding gas is transformed in a reciprocating movement which subsequently is converted into shaft rotation. Turbomachines (turbines) convert kinetic energy of a fluid directly into shaft rotation.

Small-scale CPGS use in general reciprocating prime movers; these are the spark ignition engine and the compression-ignition engine. Large-scale CPGS use turbines as prime movers. The only CPGS which does not use heat as an energy source is the hydroelectric power plant, where hydraulic energy is the input. All other CPGS represent thermomechanical converters and operate based on a specific thermodynamic cycle. The steam Rankine cycle is used in coal-fired, gas-fired, and oil-fired power stations and conventional nuclear power plants. The Brayton cycle is used in gas turbine power plants. A diesel cycle is specific to compression-ignition engines, whereas the spark ignition engine operates based on the Otto cycle.

Any CPGS has its distinct type of equipment. As already mentioned, the most important equipment is the prime mover: steam power plants develop power with the help of steam turbines, gas turbine power plants develop power using specific turbomachinery as the prime mover (this is the gas turbine), hydropower plants use various types of hydraulic turbines, and internal combustion engines use reciprocating piston–cylinder systems for their admission, combustion, compression, and expansion processes, thus generating net work output.

In steam power plants the second major piece of equipment after the steam turbine is the steam generator. Conventional steam generators use to be fired with coal, oil, or natural gas. In a nuclear power plant the steam generator is more specialized, as it is heated using various types of systems aimed at transferring heat from the nuclear reactor to the boiling water in a controlled and safe manner. The specific nuclear-based power generating systems and their power cycles, conventional and advanced, are introduced in Chapter 6 of this book.

In this chapter, the CPGSs are presented in the following order: vapor cycle power plants, gas turbine cycle power plants, gas engines, and hydroelectric power stations. For steam power plants the thermodynamic cycle of steam Rankine type is presented first with various arrangements. Coal-fired power stations with their specific steam generators are then introduced. Organic Rankine cycle (ORC) systems are discussed as a variant of Rankine cycles using an organic working fluid instead of steam. The focus is then shifted to gas turbine cycle power plants with analyses of the air-standard Brayton cycle. The section on internal combustion power generating systems covers information about the Diesel, Otto, Stirling, and Ericson cycles. The last section before chapter's conclusion discusses hydro power plants. More importantly, the CPGSs and their components are analyzed thermodynamically by writing all balance equations for mass, energy, entropy and exergy, and the performance assessments of these systems and components are carried out by energy and exergy efficiencies as well as other energetic and exergetic performance evaluation criteria.

Disciplines Involved in Offshore Platform Design

Naeim Nouri Samie MSc Hydraulic Structures, in Practical Engineering Management of Offshore Oil and Gas Platforms, 2016

2.3.5 Generator Sizing

Offshore platforms' power demand is supplied either by subsea cable from onshore power station or via diesel or gas turbine generators installed on the platform. For diesel generators, providing suitable fuel supply like diesel storage/its continuous supply and for turbine generators, gas dehydration/sweetening (to use platform gas) becomes vital in platform operation. If fuel is supplied by supply boats (during rough seasons when access to platform is difficult) adequate supply shall be provided on the platform storage. A redundant power supply for safety systems shall be provided on the platform. This is normally provided by a battery system. But its capacity is limited.

Proper generator sizing is a vital task in platform design. Chemical energy in fuel (fluid or gas) is transferred to mechanical energy by burning in engine cylinders. Up and down movement of cylinders is transferred to shaft rotating movement. Rotation of alternators' magnetic core induces electrical current in surrounding coil, which is transferred to switchboards and consumed as electrical energy. Several factors impact generator efficiency. Complete fuel burning, frictionless transfer of chemical energy to rotating movement of magnetic core, and impact of induction currents all influence total generated electrical power.

Power generation system (diesel or gas turbine) used in an offshore installation shall satisfy several criteria:

1. Shall be robust and be able to supply normal continuous demand of the offshore installation for long-term operation during all weather conditions. Generators are very large equipment. Other than replacement of small items and overhaul repairs, total replacement is very costly. Their design life shall be of the order of reservoir hydrocarbon supply.

2. Shall have suitable contingency. Schemes like 2 × 100%, 3 × 50% and 4 × 33% have been used considering factors like available plot plan area, impact of loss of production due to power shutdown, availability, possibility of maintenance, and total power demand. Loss of production due to power shutdown may become very costly. Selecting a redundancy scheme is further explained in Section 2.8.8. New start-up requires considerable man power and equipment mobilization, which considerably increases the costs.

3. Normal power demand shall cover a sufficient range of generator capacity. Too high or too low power consumption may reduce generator operating life considerably.

4. Generators shall be able to cover temporary high-power demands. This issue shall cover both an impulse surge in electrical current during heavy motor start-up or higher power demand for longer duration. The first one may last only a few seconds and the second one shall not be more than 1 h. Generator control panel may shut it down if load exceeds a certain limit.

5.

> During start-up of a single consumer, electrical current will have an impulsive peak rise. Either soft starter shall be used to reduce the high peak or generator shall be sized for this condition. This peak may be as high as seven times normal current. Each vendor provides this coefficient for its own electromotor. During calculations a high value is selected. This value shall be confirmed during vendor data review stage.

In selecting generator capacity for the first step the electrical engineer will sum up all loads acting continuously. In the next step, all intermittent loads are calculated. A contribution factor (like 30%) is selected. In some cases different factors may be selected for different types of intermittent consumers. Continuous loads plus selected percentage of intermittent loads constitute generator normal power rating. A contingency factor of 10–15% may also be applied. Project team cannot stop until all loads are accurately known, then procure generators. Therefore when load estimates are based on assumptions, higher contingency can be applied. After getting final vendor data, a reanalysis can be made to verify generator sizing. In this case lower contingency shall be applied.

In the next stage they shall consider applicable start-up scenarios and calculate the high demand of large consumers. The maximum power of different scenarios will be selected as generator power. After that platform sparing philosophy shall be taken into account. For low loads 2 × 100% spare may be selected while for higher demands, which may necessitate turbo generators, 3 × 50% or even 4 × 33.3% sparing may be selected.

Development of last-stage long blades for steam turbines

T. Tanuma, in Advances in Steam Turbines for Modern Power Plants, 2017

13.1 Introduction

Power generation systems that employ steam turbines produce more than 60% of the global supply of electricity [1] and the world electricity demand increases by more than 70% over 2013–40 in one possible scenario ([2], p. 307). Therefore, developments and practical realization of necessary technologies to enhance the efficiency and/or the output of steam turbines for power plants should be encouraged to meet the electricity demand while limiting and reducing global greenhouse gas emissions.

Fig. 13.1 shows a cross-section of a typical 1000-MW-class large-scale steam turbine with last-stage modern long blades for power plants [1]. From left to right, turbines are located as follows: high-pressure (HP) turbine, intermediate-pressure (IP) turbine and two low-pressure (LP) turbines. Steam turbine system designs including this kind of layout are optimized with regard to the efficiency, the cost, the delivery date (start-up target), the requirements from the customer specifications and the available technologies. In particular, last-stage long blades in LP turbines are the most critical parts because selection of the last-stage blade has a strong impact on the necessary number of LP casings, efficiency levels, costs, and necessary lead times of steam turbine systems for power plants.

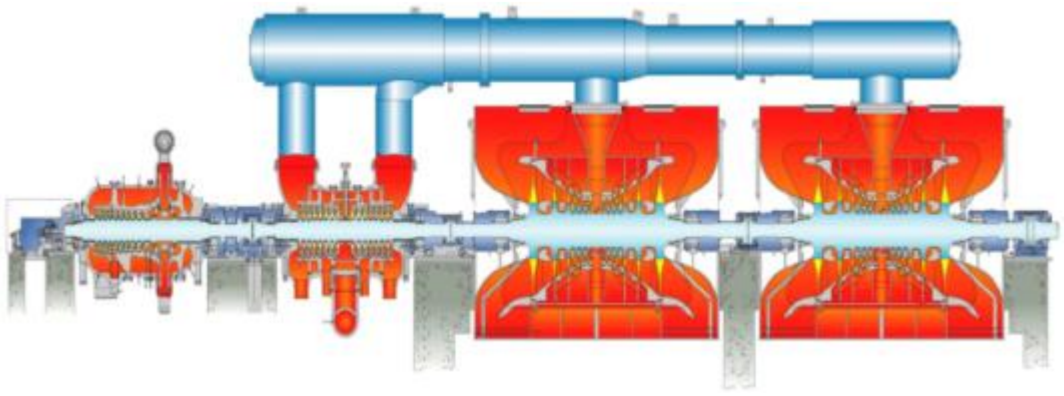


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Figure 13.1. Typical layout of a steam turbine with modern last-stage long blades.

Fig. 13.2 shows a typical LP rotor and blades for large-scale steam turbines for modern power plants [1]. The length of last-stage blades is far greater than that of the other upstream stages. Last-stage long blades developed recently by steam turbine manufacturers in the world are around 1 m in length or longer for 3600- and 3000-rpm designs.

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Figure 13.2. Typical low-pressure rotor and last-stage blades.

Fig. 13.3 gives a breakdown of typical steam turbine losses in a recent large-scale steam turbine such as the one shown in Fig. 13.1 [1]. The LP blade loss and LP exhaust loss are the largest and the second-largest losses. These losses are directly related to the last-stage long blade design and, in particular, the length of the last-stage blade. The last-stage long blade losses are the main part of the LP blade loss.

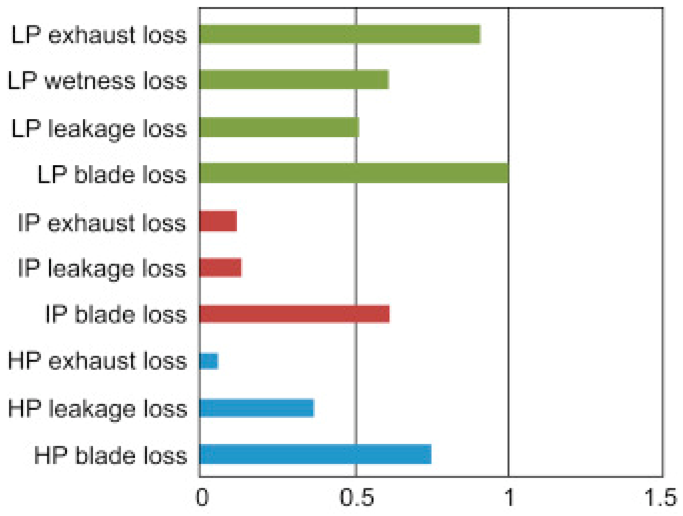

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Figure 13.3. Breakdown of typical steam turbine losses in a recent large-scale steam turbine (relative fractions of each loss to low pressure blade loss).

For these reasons, it is well known that the development of longer and highly efficient last-stage long blades is very important for steam turbine manufacturers.

Some of the critical technologies for the development of last-stage long blades are technologies for the assessment of vibration stresses induced by unsteady flows at low-volume flow conditions during start-up and shut-down operations and technologies in aeromechanics, aeroelasticity, and unsteady aerodynamics with which more efficient and longer blades can be designed.

There are many theoretical, numerical, and experimental researches on aeromechanics, aeroelasticity and unsteady aerodynamics of turbomachinery, in particular for aero engines and gas turbines. Marshal et al. [3] introduced a three-dimensional (3D) unsteady aerodynamic solver in which blade movement can be included in the aerodynamic model, using a mesh movement algorithm and a modal representation of the structural model of an aero engine fan. Tateishi et al. [4] developed fully coupled steady fluid–solid interaction and flutter simulation solvers and demonstrated their capability comparing the measured data of the NASA Rotor 67 transonic experimental fan. Aotsuka and Murooka [5] presented numerical analyses for two types of transonic stall fan flutter using their in-house computational fluid dynamics (CFD) code.

For last-stage long blades of steam turbines, Zhou et al. [6] predicted bucket forced response under typical low engine order excitation analytically and correlated it with experimental measurements. Shibukawa et al. [7] presented a series of experiments and a steady CFD study to investigate the correlation between vibration stress behavior, steady pressure and unsteady pressure fluctuation. Petrie-Repar et al. [8] presented flutter analysis of last-stage long shrouded blade using equilibrium wet steam equation of state. Megerle et al. [9] presented an unsteady aerodynamics study under low-volume flow conditions. Tanuma et al. [1] presented the development of the methodology to predict unsteady flow effects on last-stage rotating blades that have a great impact on blade mechanical design and, accordingly, also on blade aerodynamic design.

Miyake et al. [10] presented a numerical investigation of unsteady 3D un-equilibrium wet steam flow through three LP steam turbine stages including a last stage.

In this chapter, the recent technologies on developments and designs of last-stage long blades for steam turbines are explained. Some recent technologies for the assessment of vibration stresses induced by unsteady flows are also explained.

Integrated ESS application and economic analysis

In Grid-scale Energy Storage Systems and Applications, 2019

5.4.1.3 Arbitrage through peak and valley prices

Wind power generation systems' discordancy with the grid during peak and valley hours will result in shutdown and low-output operation of thermal power generating systems during these hours and thus lead to increase of coal consumption and significant reduction of economic efficiency. Moreover, the connection of large-scale wind power with the grid has an impact on the grid's security. Therefore, connection between wind power and the grid is restricted.

When fixed on-grid price mechanism is applied, ESSs, when used to regulate power supply in peak and valley hours, cannot bring benefits to the wind power plant operators or encourage power generation companies to take technical measures to improve power quality. If reasonable adjustable peak and valley prices can be applied, wind power plants can be guided to partake in the peak regulation that will alleviate the pressure for peak regulation at the power source and grid sides and beget optimization of the power generation systems in the grid. On the other hand, impact of wind power on the grid can be reduced and security of the grid can be better ensured. This will increase the uptake of wind power by the grid. If wind power is priced based on the power prices during peak and valley hours at the user side, the economic efficiency of the ESS thereof should be calculated as follows:

$$R_3 = e_i(P_{discharge,i} - P_{charge,i}/\eta)\Delta t \tag{5.32}$$

Where ei is the on-grid power price during *i* period; Δt is the periods of a day divided based on power price mechanism.

Auxiliary equipment

J. Moore, in Fundamentals and Applications of Supercritical Carbon Dioxide (sCO_2) Based Power Cycles, 2017

9.5 Summary

sCO_2 power generation systems are conceptually simple in comparison to typical Rankine or combined cycle plants; however, they require auxiliary equipment for proper operation. sCO_2 provided to the DGSs provides both buffering from loop contaminants and cooling in the case of the turbine. To reduce wear of turbomachinery components, main loop filtration is required. Inventory management system provides both initial fill and venting control of the sCO_2 quantity of the loop and the operating pressures. Pressure and temperature measurements at high pressure and temperature in the loop piping are challenging, and some suggested methods are provided in this chapter.

Methane Production from Lignocellulosic Residues in a Farm Scale System — Two Years' Operating Experience

E.C. Clausen, J.L. Gaddy, in Energy for Rural and Island Communities: Proceedings of the Third International Conference Held at Inverness, Scotland, September 1983, 1984

Power generating system

The power generating system consists of a modified four cylinder 25 kW Wisconsin air-cooled engine coupled to a 7.5 kW induction motor. The system is capable of generating 7.5 kW of electricity. The biomass used by the engine is metered and introduced via twin pressure regulators and a modified carburettor venturi, to handle the biogas. The gas pressure to the engine is supplied from storage at a pressure of 23 cm (oil). The power generation is metered and can be used by the farmhouse or put into the grid system.

An important aspect of farm energy systems is the ability to sell electricity to the local power company. Such an arrangement eliminates the need for large gas storage systems, and also provides an additional source of income. The use of an induction motor ensures that the electricity is in phase with the line power and also provides shut down safety features.

APPLICATIONS – STATIONARY | Residential Energy Supply: Fuel Cells

L. Jörissen, in Encyclopedia of Electrochemical Power Sources, 2009

Summary

Residential CHP systems are a promising technology to efficiently supply heat and electricity at reduced emissions to private homes and small businesses. Furthermore, increased market penetration of CHP and other DG technologies will reduce the overall grid load.

Considerable efforts are in progress to develop residential CHP products based on PEMFC and SOFC technology having an electric power output of 1–2 kW for single-family homes and up to 5 kW for small multi-family homes and small businesses.

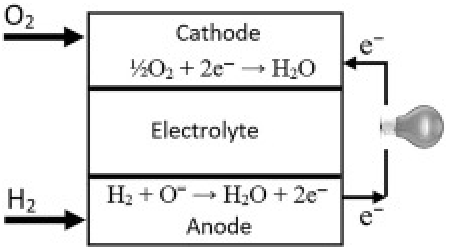
Considerable technical challenges are in the cost and durability of systems. Furthermore, higher-energy-efficient building standards pose an additional challenge by increasing the electricity and lowering the heat demand.

In Japan, a large-scale field trial involving more than 3330 systems has started in 2005. The first commercial products are expected in the year 2009. In Germany, a field demonstration program involving approximately 800 systems has started in 2008.

Entropy and fuel cells

9.1 Introduction

The power-generating systems that we have discussed so far are heat engines, which produce useful work by converting a portion of heat supplied through a high-temperature reservoir, fuel combustion, or a hot stream. Fuel cell is a device that produces electrical energy by converting the chemical energy of a fuel through a series of electrochemical reactions. A fuel cell consists of the following main segments: anode, cathode, and electrolyte (Fig. 9.1) The primary fuel of most fuel cells is hydrogen, which is supplied to the anode. The cathode is fed by an oxidizer, i.e., oxygen or air. The reactions taking place in the anode and cathode of a fuel cell include


O2
Cathode
½O2 + 2e− → H2O
e−
Electrolyte
H2
H2 + O= → H2O + 2e−
e−
Anode

Conclusion

- Using BIM as a tool to update the flow of information during a project is just as critical as doing it the first time. BIM tools will continue to develop in their ability to be streamlined, but current processes allow a BIM-enabled construction manager to complete tasks with relatively good efficiency.
- As users become more proficient with the software and the process to which the software is applied, these tasks will be even faster. In this chapter, you took an updated Revit file and linked the new file into Innovaya to update your quantities and costs, you used the updated Revit file to run a schedule clash detection report in Navisworks, you exported your clash report to Navisworks and Adobe Acrobat Professional, and you updated ...

Reference

- It source from bim model technologies.com