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Improving Efficient Smart Management of Power Transmission Network Using BIM Technology

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Abstract

The advent of Building Information Modeling (BIM) technology has revolutionized infrastructure projects, including electrical systems. This research explores the transformative impact of Building Information Modeling (BIM) technology on infrastructure projects, with a specific focus on optimizing critical components within power grids, such as transmission lines and substations. The study advocates for the seamless integration of BIM, creating digital modeling that encompasses various input data, from geometry to costs. This integrated approach enhances real-time collaboration, mitigates errors during design, and streamlines construction processes by aiding scheduling, resource allocation, and progress monitoring. Additionally, the research extends its scope to the integration of BIM in MicroGrids (MGs), highlighting the potential to enhance efficiency and reliability in these decentralized power networks. By bridging the gap between macro and micro perspectives, the study aims to contribute to the advancement of SmartGrid (SG) frameworks for more sustainable and efficient energy distribution.

***Keywords**: BIM (Building Information Modeling), Transmission lines and substations, Digital Modeling, Micro Grids, Smart Grids (SG), System Manageability, Reliability.*

Abbreviations

BIM	Building Information Modeling
GIM	Grid Information Model
SG	Smart Grid

1. Overview

Science and technology have been rapidly improving due to the rise of the Internet of Things (IoT), which allows for the interconnection of devices and data collection. Consequently, there is an increasing demand for applying various technologies such as design, monitoring, and operation in industries in general and power systems in particular. Building Information Modeling (BIM) technology has emerged as a powerful tool for designing and managing infrastructure projects, significantly enhancing efficiency and reliability in power systems. In Vietnam, the government is actively promoting the adoption of BIM in the construction and development planning of power system infrastructure, which is a significant step towards the digitization of the entire power system [4].

Despite the recent advancements in power system engineering, challenges remain in creating information systems and databases due to their complex and diverse nature. The application of Grid Information Model (GIM) technology has proved to be instrumental in addressing these challenges in the digital transformation of power systems. GIM leverages parameterization to construct 3D models, which facilitates the seamless digital transfer of projects. This digitized and virtualized information system encompasses crucial details about building structures, including materials, specifications, system design, and equipment operating characteristics [5].

Implementing the BIM technology in Vietnam's electricity sector can enhance construction management, ensure safety, and reduce costs throughout the project lifecycle. This research focuses on the scalability possibilities of BIM in power systems, specifically by optimizing the entire lifecycle through adjusting parameters such as the insulation chain based on contamination zones along the transmission line [6]. When it comes to ensuring accurate information in construction and maintenance standards, traditional management methods often encounter difficulties in coordinating effectively with stakeholders. To overcome this challenge, this study proposes the integration of technology to create a dynamic digital model of equipment on the transmission line. This model includes initial information components such as geometry, materials, and cost, which allows for the dynamic adjustment, calibration, and control of parameters at every stage of the project. Furthermore, the model enables real-time collaboration, simulation, and analysis during the design phase, minimizing errors and optimizing layouts for efficient construction. The BIM supports project scheduling, resource allocation, and progress monitoring as the project moves into

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the construction phase. The digital modeling capabilities can be used to simulate and evaluate various scenarios, enhancing safety measures and minimizing risks in future maintenance and operation [7].
The research findings aim to improve the management and reliability of the transmission system beyond the power grid, reinforcing the potential of BIM technology in areas such as smart grids (SG). In particular, BIM integration can be crucial in optimizing microgrids' efficiency and resilience. These are smaller-scale power systems that can benefit greatly from the use of BIM technology [8].

2. Model of the Transmission Line

2.1. Insulation system modeling

Leveraging 3D BIM, the design of the overhead line progresses as follows, refer to Figure 1. First, based on the base map, 2D tower locations are chosen in Revit, assigning them elevation, path code, and other relevant data. Next, a standardized family library, established beforehand, allows for automatic tower selection and modeling at each designated point. Tower information dictates the automatic generation of components at their specified positions, including the sorting of loop and phase sequences for suspension or tensioning strings. Finally, the 3D visualization environment facilitates model adjustments to finalize the design.

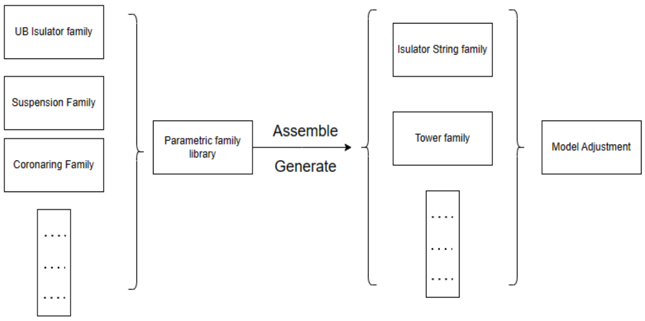

Figure 1. Design processes based on BIM technology.

When designing a 500kV power transmission line, it's important to adjust the insulation chain parameters based on the contamination zone. Additionally, the insulation parameters must be adjusted based on the construction location. By using BIM technology, we can automatically modify the insulation string parameters based on environmental factors and creepage distance standards. This information can be found in Table 1 and Figure 2.
Formula determines the number of insulating bowls in the chosen series:

$$n = \frac{d.U_{max}}{D} \quad (1)$$

where: n is the number of insulation bowls in a string.
d is the creepage standard (20mm/kV).
U_{max} is the maximum working line voltage (kV).
D is the creepage distance of an insulation bowl (mm).

According to electrical equipment regulations, the number of insulating bowls in the station is increased by 1 bowl so that the insulating bowls will be: n + 1 [9]-[11].

Table 1. IEC insulation parameters.

Designation	Failing load	Diameter D	Nominal spacing P	Creepage distance	Coupling	Creepage standards
U 40B	40	175	110	190	11	20
U40BP	40	210	110	295	11	20
U70BS	70	255	127	295	16	20
U70BL	70	255	146	295	16	20
U70BLP	70	280	146	440	16	20
U100BS	100	255	127	295	16	20
U100BL	100	255	146	295	16	20
U100BLP	100	280	146	440	16	20
U120B	120	255	146	295	16	20
U120BP	120	280	146	440	16	20
U160BS	160	280	146	315	20	20
U160BSP	160	330	146	440	20	20
U160BL	160	280	170	340	20	20
U160BLP	160	330	170	525	20	20
U210B	210	300	170	370	20	20
U210BP	210	330	170	525	20	20
U300B	300	330	195	390	24	20
U300BP	300	400	195	590	24	20
U400B	400	380	205	525	28	20
U530B	530	380	240	600	32	20

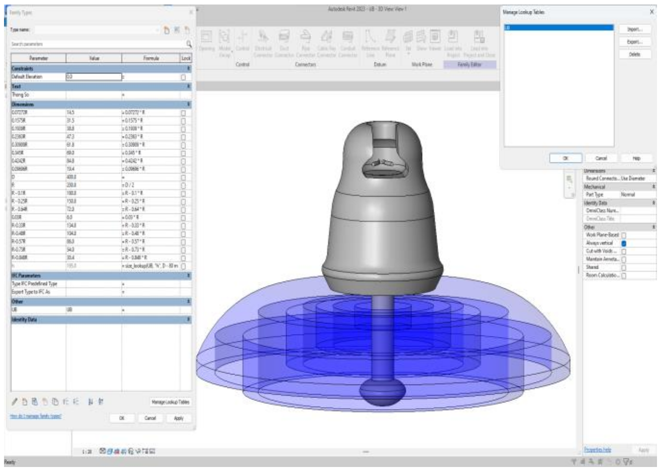

Figure 2. 3D model of insulator can change parameters.

According to electrical equipment regulations, the number of insulating bowls in the station is increased by 1 bowl, so the insulating bowls will be: n + 1 [5].
When power transmission lines are exposed to environments with high levels of contamination, the insulation parameters can be automatically increased to ensure safety and optimal performance. Conversely, in a clean environment, the parameters can be adjusted to save costs while maintaining stable performance.
When designing the insulation system for 500kV lines, it is important to consider not only the insulation parameters but also crucial components such as suspension strings, tension strings, and other necessary accessories. Suspension Strings ensure the stability and safety of the transmission line, while Tension Strings prevent collisions between the conductor and surrounding structures. Other accessories like clamps, connectors, and fasteners must be designed and selected with care to ensure the line is safe and reliable.

2.2 Transmission tower model

Transmission towers are the physical foundation for supporting power transmission lines, keeping wires at a fixed height, and helping to transmit power from substations to different consumption locations to ensure the safety of the power system and the people. In addition, preventing electrical wires from contacting the ground or surrounding structures prevents dangerous incidents like short circuits. Additionally, these towers are designed to resist environmental impacts such as wind, loads, and inclement weather, all of which contribute to the reliable operation of the electrical system [10].

The positioning of towers is strategically planned to facilitate access for maintenance and repair services, enabling quick troubleshooting and maintaining optimal system performance. Towers must comply with technical regulations and safety standards to ensure the uniformity and safety of the electrical system nationwide or in a specific area.

BIM allows for the creation of 3D models of Transmission Towers, including both Straight support and Corner tension Tower. These models include precise details such as the size, shape, and location of each tower, as shown in Figures 3 and Figures 4.

Figure 3. 3D model of the Straight Support Tower.

Figure 4. 3D model of the Corner Tension Tower.

2.3 Device statistical model

Before starting construction on 500kV power poles, performing a detailed design and simulation of materials and equipment is crucial. Early-stage design and simulation using BIM helps detect and fix errors, preventing confusion during construction and later use. By utilizing BIM, the specifications and materials required for both support and tension towers can be optimized based on specific project requirements and environmental conditions.

Rapid statistical tools can assist in aggregating materials and design data, enabling project managers and engineers to assess performance and progress effectively. Table 2 presents relevant information such as the amount and type of supplies required, cost, count, and other vital factors.

Table 2. Statistical table of details equipment

<Statistical details Take off>

A	B
Components	Count
Double Tension String Family	1
Adjustable Extension Link 392-584	1
Adjustable Extension Link 392-584	1
Adjustable Extension Link 300-450	1
Adjustable Extension Link 300-450	1
Corona Racquet	1
Yoke Abstanhalter	1
Yoke Abstanhalter	1
Corona Racquet	1
Adjustable Extension Link 300-450	1
Compression Dead End Clamp	1
Compression Dead End Clamp	1
Adjustable Extension Link 300-450	1
Compression Dead End Clamp 30o	1
Compression Dead End Clamp 30o	1
bolt set O22x42	1
bolt set O22x42	1
bolt set O22x42	1
bolt set O22x42	1

During the construction of a 500kV Transmission Tower, the use of advanced statistical tools can ensure that the columns are accurately and efficiently designed from the planning phase to the actual implementation. This minimizes the occurrence of errors and confusion, improving the reliability of 500kV power transmission systems and ensuring their stable operation under all conditions.

2.4 Intuitive, easy collision detection

During the design of transmission and insulation systems, it is crucial to create accurate 3D models of all the components involved. A clear view of all details and interactions between elements (tower positions, insulation, cables) is crucial for design engineers. Having a 3D model allows them to detect and quickly resolve any potential collisions, including ensuring that there are no collisions between cables and towers or other elements of the insulating system. This is illustrated in Figure 5.

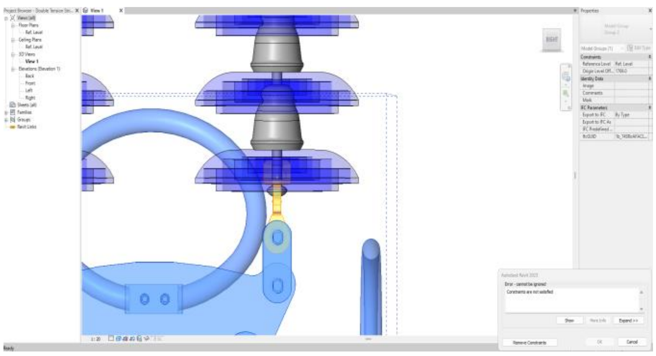

Figure 5. Collision warning.

BIM can aid in optimizing the placement and height of transmission towers. Calculating and displaying the optimal position of the tower can help reduce costs and improve the efficiency of the transmission system. BIM technology can also ensure that the tower is positioned in a way that minimizes collisions with surrounding structures, thereby increasing the safety of the system.

Once a project is finished, the research conducted during the project remains valuable. It can be used to maintain information about the transmission system. This information is beneficial in predicting potential failures, such as those related to the insulation system or towers, before they cause a significant breakdown. By identifying and addressing these issues early, operational continuity can be improved, and downtime can be reduced.

The BIM-based information management system simplifies project management and transmission system maintenance. It streamlines tasks like determining maintenance cycles, scheduling replacements, and system safety.

3. Dynamo node model in the design phase

3.1 Load multiple families by Dynamo

The traditional method of loading families into Revit is to manually browse the family file and then click the "Load" button. This method can be time-consuming and error-prone, especially when loading a large number of families.

The proposed method uses Python code to load families into Revit automatically. The code can be written to load all families in a specific directory, load families based on their name or type, or load families and set their properties. Figure 6 presents several Python code snippets that illustrate the process of automatically loading families into a Revit project.

```python
import os
import clr
import Autodesk.Revit.DB
from Autodesk.Revit.DB import IFamilyLoadOptions, FamilySource, Transaction

doc = __revit__.ActiveUIDocument.Document

class FamilyLoadOptions(IFamilyLoadOptions):
    def OnFamilyFound(self, familyInUse, overwriteParameterValues):
        overwriteParameterValues = True
        return True
    def OnSharedFamilyFound(self, sharedFamily, familyInUse, source, overwriteParameterValues):
        source = Chuoicachdien.Fmily
        overwriteParameterValues = True
        return True
    def load_family(folder_path=D:\NCKH\BIM\Family\Part 2, Chuoisu):
    family_path = os.path.join(folder_path, file_name)
    if os.path.exists(family_path) is False:
        return 'Path does not exist.'
    family_loaded = clr.Reference[Autodesk.Revit.DB.Family]()
    t = Transaction(doc)
    t.Start('Load Family')

    loaded = doc.LoadFamily(family_path, FamilyLoadOptions(), family_loaded)
    if loaded:
        family = family_loaded.Value
        symbols = []
        for family_symbol_id in family.GetFamilySymbolIds():
            family_symbol = doc.GetElement(family_symbol_id)
            symbols.append(family_symbol)

        for s in symbols:
            try:
                s.Activate()
            except:
                pass

        t.Commit()
        return symbols

    else:
        t.Commit()
        return 'Family already exists in project.'
```

Figure 6. Python autoload family code.

Revit software allows loading only one type of Family at a time. To import multiple families simultaneously, engineers can utilize Dynamo, as demonstrated in Figures 7 and 8. This method proves to be a time-saving technique for engineers.

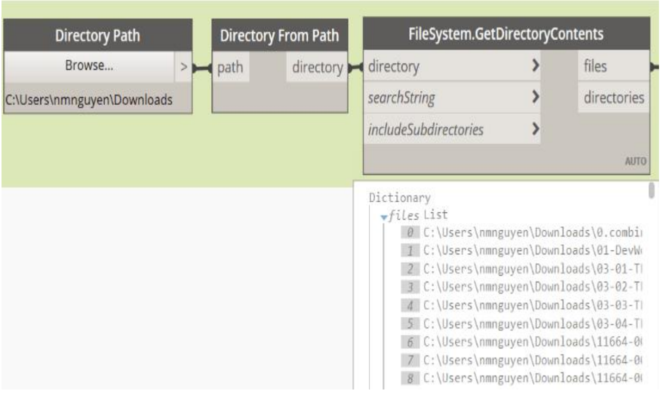

Figure 7. Node Dynamo load multiple families.

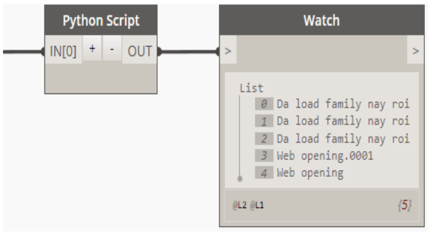

Figure 8. Node Dynamo loads multiple families.

3.2 Reset Sheet Number by Dynamo

When dealing with large projects that contain numerous sheets, resetting page numbers manually can be both a time-consuming and error-prone task. To tackle this challenge, Dynamo offers an automated solution that saves time and reduces the likelihood of errors. You can take a look at the Dynamo model in Figures 9 and 10.

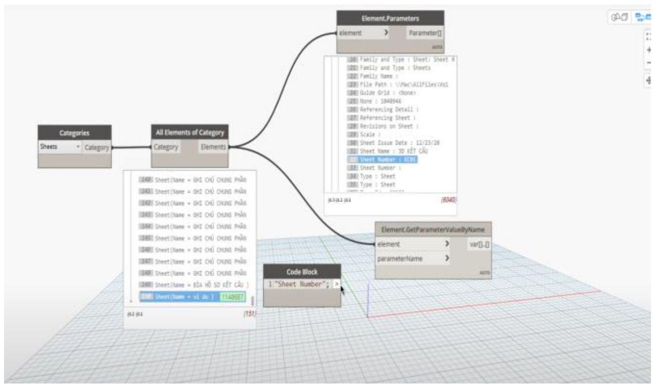

Figure 9. Note Dynamo Reset sheet number.

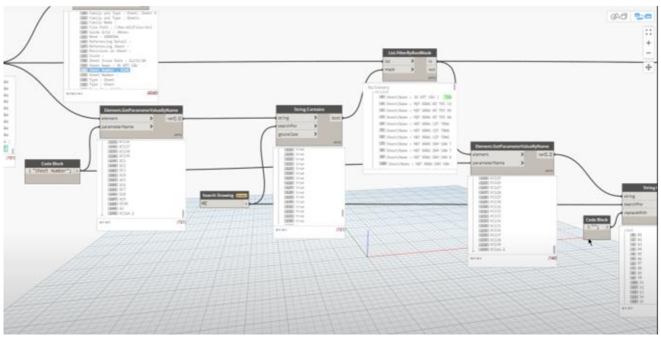

Figure 10. Note Dynamo Reset sheet number.

4. Results and discussion

The insulation system model is simulated by combining different commands. The simulation is done before and after changing the number of insulation chain parts and fittings, as shown in Figures 11 and 12. The parameters can be changed flexibly based on technical requirements and the level of contamination in the environment.

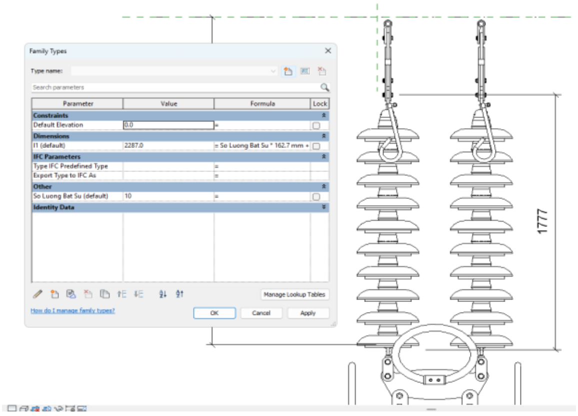

Figure 11. The Double Tension String model before changing the number of porcelain bowls.

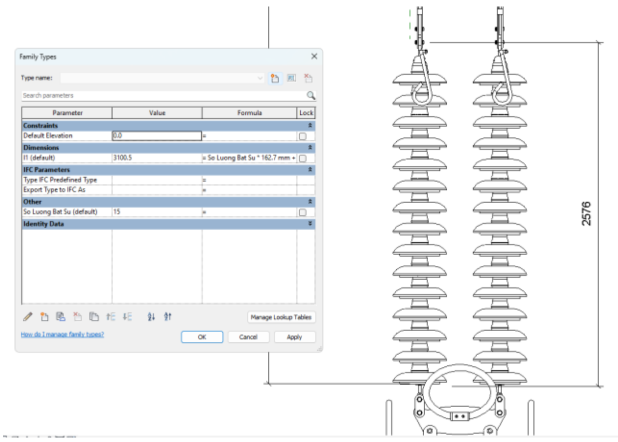

Figure 12. The Double Tension String model after changing the number of porcelain bowls.

Revit commands and tools are used to create 3D models of insulated strings and accessories, which includes determining their shape, size, and placement in the model. See Figure 13 for reference.

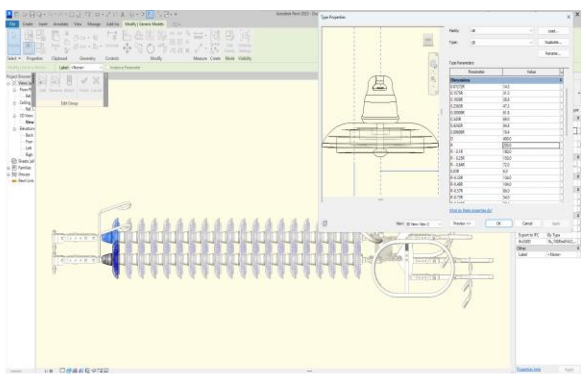

Figure 13. Automatically change the values of insulator strings according to catalogs

Revit provides the flexibility to modify the specifications of insulation string parts and accessories according to specific project needs. This includes changing specifications such as insulation type, material, quantity, and other technical factors to meet environmental and technical standards. Figures 14 and 15 illustrate these modifications in detail.

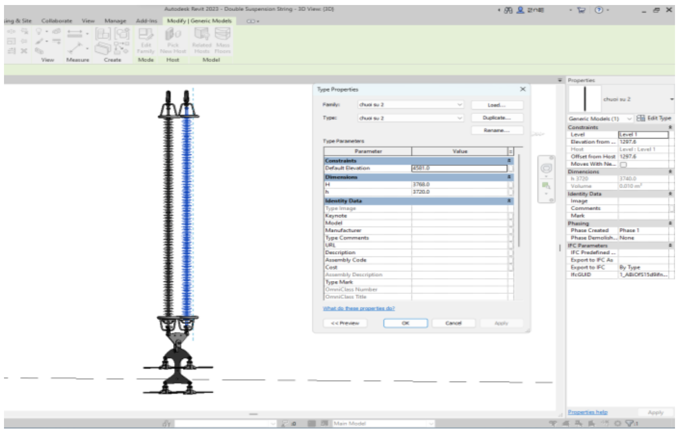

Figure 14. 3D model Double Suspension String Polymer.

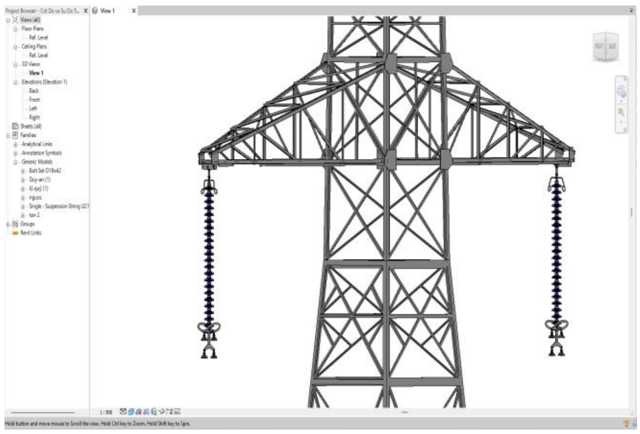

Figure 15. 3D models of towers and insulation string.

Simulations are conducted using Civil 3D and Infraworks software to create realistic visual positions of the transmission line, based on the complete design of the insulated string and towers system in Revit.

Figure 16. Proceed to create routes on Civil 3D.

After importing data into InfraWorks, it can be viewed and tested in the model to ensure accuracy and compatibility with the project.

Figure 17. Insulated Strings and Towers Simulated in Infraworks.

5. Conclusion

The combination of Revit, Civil 3D, and InfraWorks creates a powerful and interconnected workflow that optimizes design, simulation, and construction management for infrastructure projects. This enables a visual 3D model of the project, helping architects, engineers, and other stakeholders better understand the design and interact with it. As a result, this improves the overall understanding and aesthetics of the project [6], [10].

Automated tools can help create and manage different parts of a project, ranging from engineering drawings to material lists. These tools significantly reduce the time and effort required for repetitive tasks. Additionally, they provide a streamlined way to manage changes and updates in the project. By tracking previous versions of the model, variations, and interactions between versions can be identified.

Furthermore, the integration of project progress information, technical documentation, and project management into the BIM model can significantly enhance project management and construction supervision.

BIM facilitates compliance with international design standards when working with international customers or partners on projects in Vietnam.

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