BES226112

The Next-Level BIM Electrical: Embedded Analysis Using Revit API

Ahmed Attia

Ahmed.attia@dar.com

Learning Objectives

- Learn how to use the Revit API for Electrical analysis
- Learn how to use a simple database to store basic information such as cables data
- Learn how to save and migrate calculation settings among different models
- Learn to do all of the above in an integrated workflow

Description

For a while, MEP (mechanical, electrical, and plumbing) disciplines in general, and electrical in particular, have been somewhat behind architecture and structure disciplines when it comes to utilizing BIM (Building Information Modeling) capabilities; hence, electrical engineers usually used BIM software as a drafting tool while keeping the same old calculation sheets and process. The purpose of this class is to give a detailed approach on how electrical analysis and workflow can be embedded successfully in BIM software, to motivate MEP and electrical engineers to take the design process to the next levels—not just by the integration between analysis software, but by preparing a full workflow. The lecture will describe embedding electrical analysis using Revit software, Revit API, and simple database; following electrical design tasks such as feeder sizing and protection sizing; explaining how Revit is used as the main tool and central platform for the electrical design process; and making the electrical and MEP engineers think of the next level.

Speaker

Ahmed Attia is a Senior electrical engineer - BIM specialist for DAR AL HANDASAH Giza, Egypt. Ahmed is a Licensed Professional Engineer with over 11 years of experience in the field of electrical design in AEC industry. He participated in many mega projects in the Middle East, including high rise buildings, airports, and electrical infrastructure. As part of his job at DAR Al HANDASAH, Ahmed has been working on developing electrical BIM workflows, with a focus on electrical analysis and BIM for sustainability.
Ahmed.attia@dar.com

Contents

Introduction

How should Revit affect electrical design?

> Save design time?
> Save budget and man-hours?
> Improve design accuracy?
> Cut on resources?

Our goal is all of this and it's called optimization (Fig.1), geometry-based disciplines like Architecture and structure are approaching that goal, but for MEP and electrical especially, we are still far behind it, although the real value of BIM is in leveraging the information contained in model, MEP still lacks a lot of needed information to be present.
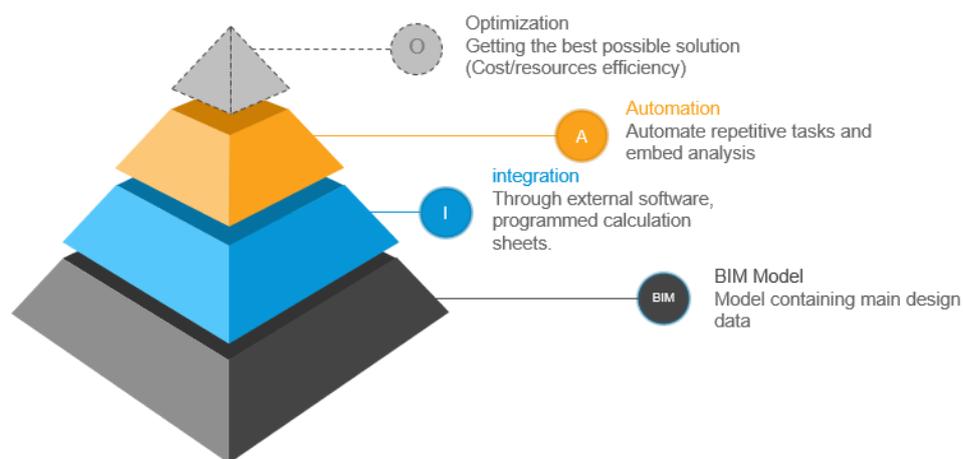Since we are still struggling with the second step of our path which is integration, various electrical design tasks are still far from being performed by BIM software and our ultimate target until now has been to get the data in and out of the model while keeping our old process and calculation sheets, why are we still stuck at this point?, that is the question to ask.

Future of Electrical BIM

Although we can develop considerable quality electrical models, the large part of our design tasks which comprises of advanced analysis like cable sizing and short circuit calculations still can't be done inside Revit (few add-ins are available for analysis with many limitations), and that makes Revit for us like an intelligent drafting tool.
Integration with external software is still limited, with major analysis software moving slowly into BIM, and integration with our classical excel sheets will not enable us of automating the process to eliminate time waste and maximize accuracy as mentioned before.

This handout will present how Revit can be used as a "design platform" that includes most electrical design tasks using Revit API capabilities and a simple methodology.

Optimization
Getting the best possible solution
(Cost/resources efficiency)

Automation
Automate repetitive tasks and
embed analysis

integration
Through external software,
programmed calculation
sheets.

**BIM Model**
Model containing main design
data

BIM future map (Fig. 1)

Why are we still stuck with analysis?

MEP analysis and electrical especially are falling behind the BIM development steps, although it is possible to embed analysis inside Revit, finding a full global solution is still hard for the following reasons(Fig.2):

- Most of the commonly used analysis software packages still aren't equipped with usable Revit add-ins or any form of communication with Revit
- Engineers perform different types of analysis that are usually dependent on each other and interconnected where they feed into each other and include referencing tables, charts, in addition to multiple conditions that will even lead to using different formulas.
- External software packages already offering Revit integration capability doesn't comply with all codes or regulations, while code complying software might not offer integration.
- When analysis is done using programmable in-house excel sheets, because they offer a flexibility of "experience-based assumptions", and integration with Excel will be limited to import/export only.
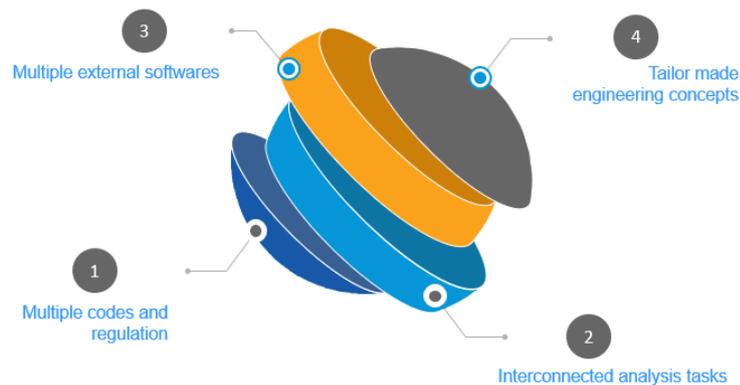
Obstacles facing BIM for analysis (Fig. 2)

## Developing the process - Revit as a design platform

Turning Revit into a "design platform" with embedded analysis capabilities might be a better option than keeping the classical workflow while using Revit at the same time or reverting to unavailable 'seamless' integration with external software.
Revit thankfully offers the option of using its API "Application programming interface" to add extra capabilities to the standard package through an "add-in".
But to perform advanced analysis through the API, we must develop a vision of the expected "closed loop" design workflow and a methodology to embed analysis which are more important than advanced programming skills, such process should consist of or at least satisfy the purpose behind each of the following (Fig.3):

- An external database that contains all necessary external data required for analysis such as equipment manufacturer data, standard ratings.
- Global settings input to customize analysis based on different regulations, design conditions, engineering decision, etc.…,
- Revit with embedded analysis logic and calculations using the API

- User preferences, default settings data storage, ability to track model changes, etc... (Check Revit extensible storage pag.10)
- Additional custom user interfaces allowing engineer input of calculation settings or viewing/editing analysis database
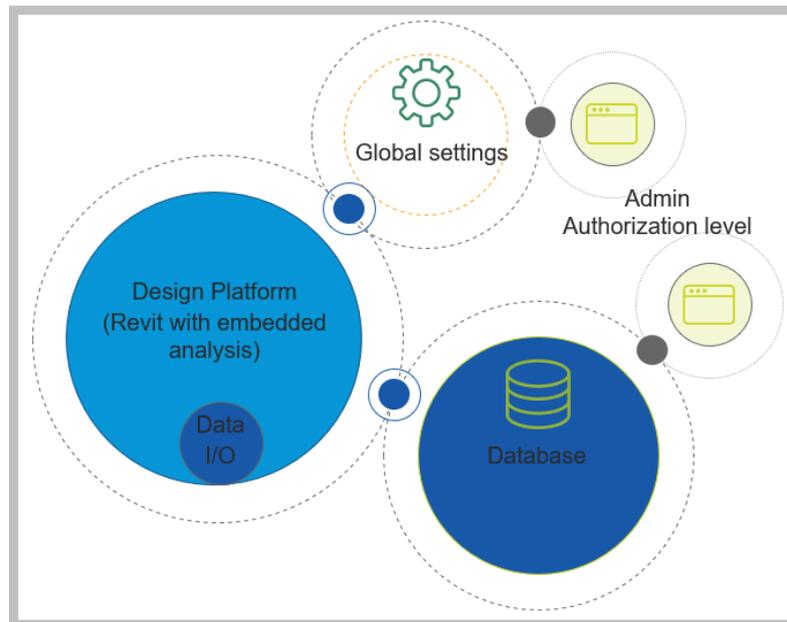
Design Platform (Fig. 3)

How embedding analysis will affect classical design process

To better assess the effect of automating electrical analysis inside Revit on the electrical design process, we need to define the classical design process in more detail and divide into generic tasks. Showing how automation would affect the overall accuracy and productivity. This are the main tasks which are performed in any design process:

- Concept and design criteria
- Data input
- Calculation
- Data tabulation i.e. panel schedules, feeder data schedules, etc.
- Drafting and layout
- Re-design or design changes

Now we can easily define affected tasks:

- ➢ for data input, automation would save a lot of time by minimizing the task or eliminating it completely in some cases.
- ➢ calculations would save the time of repeating data input inside design software or export from BIM software.
- ➢ data tabulation would be eliminated entirely by the use of standard templates and carefully planned parameters.

not to mention higher overall accuracy and fewer errors in case of design changes.

Steps to implementation

The process described below for utilizing Revit for electrical analysis is not intended as the only solution, but as a tested working approach, some steps might vary depending on the final goal and complexity of analysis required, but the following should apply to most electrical analysis commonly performed by electrical engineers.

1. Engineering analysis breakdown structure

To start planning your analysis platform, you need to re-arrange your analysis into a software-friendly structure (Fig.4), cut into smaller blocks and label each part based on where it belongs in your design platform, through the following steps:

A. Determine target analysis
Defining your target is the first step in this process, whether it is short circuit analysis, equipment sizing, etc.

B. Define global Settings
Settings are values that apply to the whole project, usually pre-set at project start and affect the final analysis output, i.e. Ambient temperature, Frequency, Voltage levels, etc.

C. Summarize calculation references (Database)
Calculation references are usually a set of values, tables or charts used as reference for analysis process to extract data required for analysis such as: the next available standard rating, extract specific manufacturer data to feed into analysis or choose code regulated factors according to design conditions, this might include cables manufacturer data, breaker ratings or equipment sizes.

D. Define analysis Inputs
Inputs are values required to process calculation formulas, usually provided by engineer and can take many forms (such as Load value, Load type, installation conditions, etc.).

E. Prepare list of formulas
This are all the formulas, equations, required to produce the final output of targeted analysis.

F. Define analysis outputs
This can be summed as all information, values resulting from performed analysis and is considered the final deliverable of the analysis process.
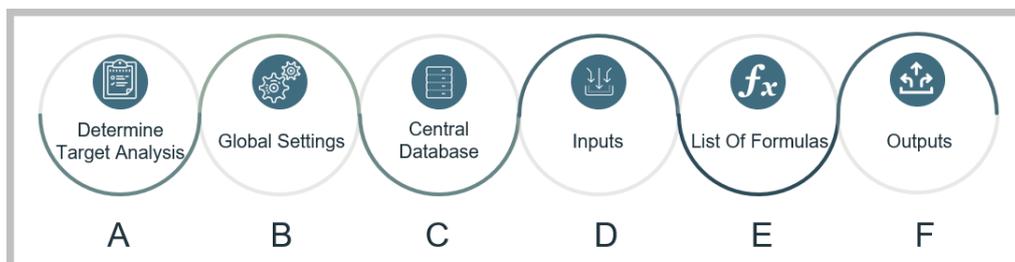
Analysis breakdown structure (Fig. 4)

2. Standardizing BIM objects (Families, Templates)

The second step of this methodology is to make sure that all your families, templates, etc...
are ready for the transition, all the data needed for your design process should either be
available or have the correct list of parameters and Revit settings carefully planned to match
the final outcome. Carefully planning your families' library and templates in Revit is a crucial
step to the success of this process.
Electrical families in Revit are ready with basic system parameters that define main electrical
characteristics, but parameters required to perform any kind of advanced analysis are not
available, that's why they should be manually created inside Revit.
Note that, this is an evolving process where you will continuously develop your central
resources (families, templates) along with your analysis platform features.

2.1. How to plan each electrical family in Revit?

The following are the basic parameters categories you need to plan for your families,
as it progresses, you will add, remove, associate parameters to one another or
create formulas connecting them:

- Input parameters
- Outputs
- Analysis flow control (i.e. yes/no parameters to enable/disable element
  calculations)

create a simple spreadsheet detailing parameter type, group, measurement unit,
usage, might be a good idea at this point (Fig.5)

Added To	Shared Parameter	Discipline	Type	Group	Electrical Circuits	Electrical Equipment	Electrical Fixtures	Lighting Devices
System	Circuit Number	-	-	-	Instance	Instance	Instance	Instance
System	Panel	-	-	-	Instance	Instance	Instance	Instance
Family	Load_Classification	Electrical	Load Classification	Electrical - Loads	-	Type	Mixed	Type
System	Apparent Load	Electrical	Apparent Power	Electrical - Loads	-	Instance	Instance	Instance
Mixed	Power_Factor	Common	Number	Electrical - Loads	-	Mixed	Mixed	Mixed
Mixed	Element_Name	Common	Text	Electrical - Loads	-	Type	Mixed	Instance
Mixed	Element_Rating	Common	Text	Electrical - Loads	-	Type	Instance	Instance
Mixed	True Power	Electrical	Wattage	Electrical - Loads	-	Type	Mixed	-
Family	Incomer_Cable_Size	Common	Text	Electrical - Loads	-	Instance	-	-
Family	Incomer_Cable_Type	Common	Text	Electrical - Loads	-	Instance	-	-
Family	Incomer_Rating_A	Common	Text	Electrical - Loads	-	Instance	-	-
Family	Incomer_Type	Common	Text	Electrical - Loads	-	Instance	-	-
Family	Duty-Standby	Common	Yes/No	Electrical - Loads	-	-	Instance	-
Family	Starter_Type	Common	Text	Electrical - Loads	-	-	Instance	-
Family	MCB_Trip	Common	Integer	Electrical - Circuiting	Instance	-	-	-
Family	MCB_Frame	Common	Integer	Electrical - Circuiting	Instance	-	-	-
Family	Total_Connected_Load	Common	Number	Electrical - Loads	Instance	Mixed	Mixed	-
Family	Normal_Demand_Load_KW	Common	Number	Electrical - Loads	Instance	Mixed	Mixed	-
Family	Normal_Demand_Factor	Common	Number	Electrical - Loads	Instance	Mixed	Mixed	-
Family	▾ential_Demand_Load_KW	Common	Number	Electrical - Loads	Instance	Mixed	Mixed	-
Family	Essential_Demand_Factor	Electrical	Number	Electrical - Loads	Instance	Mixed	Mixed	-
Project	LTG_DF	Common	Number	Electrical - Loads	-	Instance	-	-
Family	SC Rating	Common	Text	Electrical - Loads	-	Instance	-	-

| Maintenance	Links	EL Equipment	Containment	EL Fixtures	LTG Fixtures	LTG Devices	Annotations	Tags

Parameters planning (Fig. 5)

3. Building activity flow diagram

The definition of an activity flow diagram is "a flowchart to represent the flow from one activity to another activity. The activity can be described as an operation of the system." This is simply laying out analysis steps in the most logical order possible combined with the following:

- Data extraction stages
- Data validation (is the data correct or sufficient for the next analysis step?)
- Which Revit elements or categories to extract data from or write data to
- Calculation steps along with required formula at each step
- When to interact with the database and what to retrieve

Figure 6 demonstrates a sample activity flow diagram for voltage drop calculations.
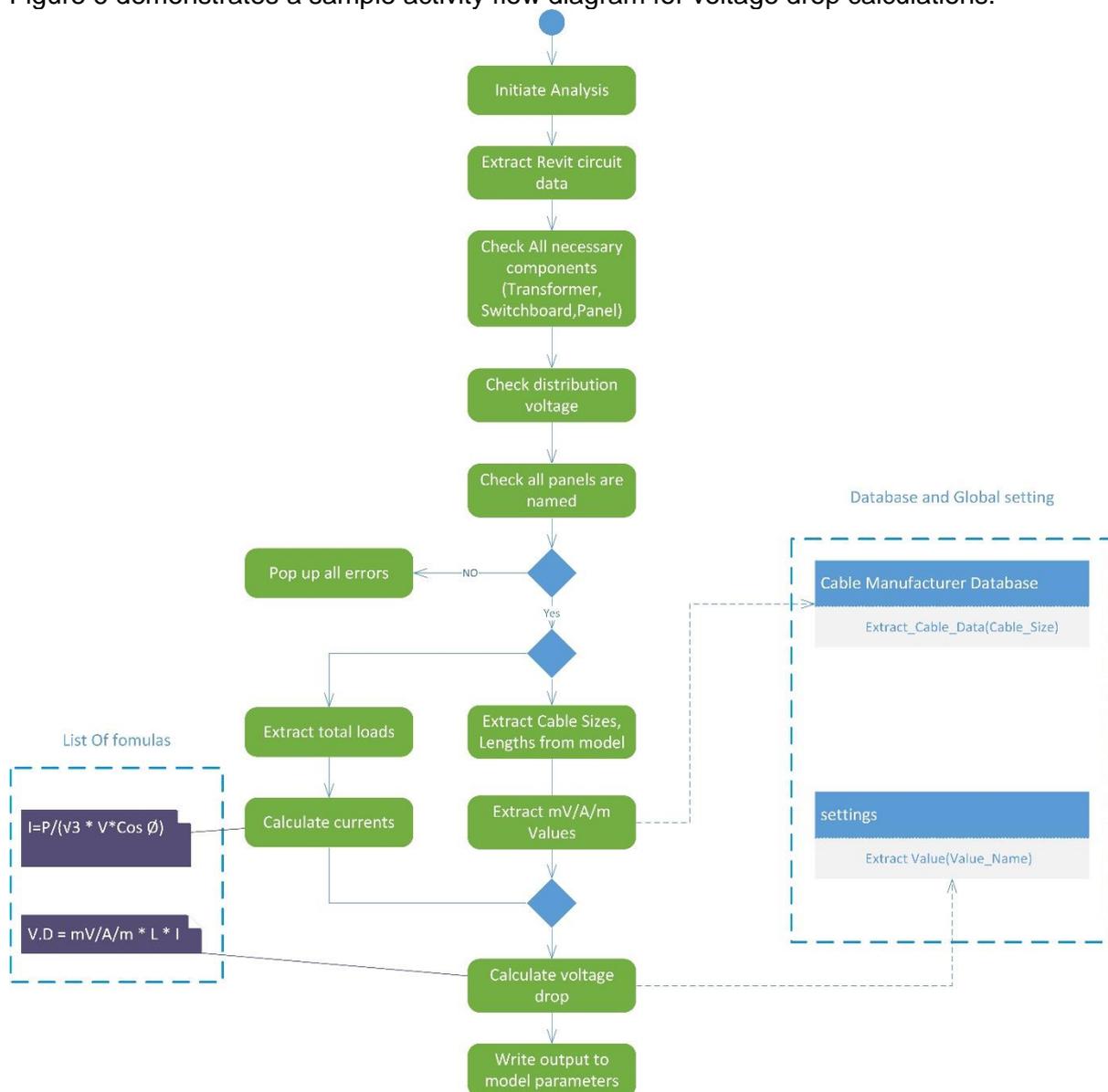
Sample voltage drop calculation activity flow diagram (Fig. 6)

4. Build your database

Performing advanced analysis or calculations involves most of the time, equipment or devices selection from a standard set of manufacturer ratings tables, charts or any form of structured data needed.

This data can't be stored inside Revit due to its complexity, that's why we need a form of an external database and to create such database the following steps are recommended:

- Determine target analysis required references (cables data, protection devices data, etc.)
- Define specific fields (C.B. ampere frame, C.B. ampere trip, cable cross section, current carrying capacity, etc.)
- Define your technical sources or references (manufacturer data, code)
- Determine your database management system (MS Access, SQL, Cloud)

Moreover, you need to think of the following additional characteristics:
  formats, precision, units conversion?
 how "editable" your database will be?
  is it fixed or updated regularly?
  who is authorized to access the database in editing mode?
  do you need an external user interface (outside Revit) to edit the database?

once you got all that figured out, you are ready to tabulate your data into corresponding tables (Fig. 7), your database might include for example: standard ratings, capacities at different operating conditions, manufacturer-specific data, etc.

Another usage of the database is to store user-specific preferences, settings, previous analysis records, but here comes a Revit API important feature that is more suitable for such tasks, which is Revit's extensible storage.
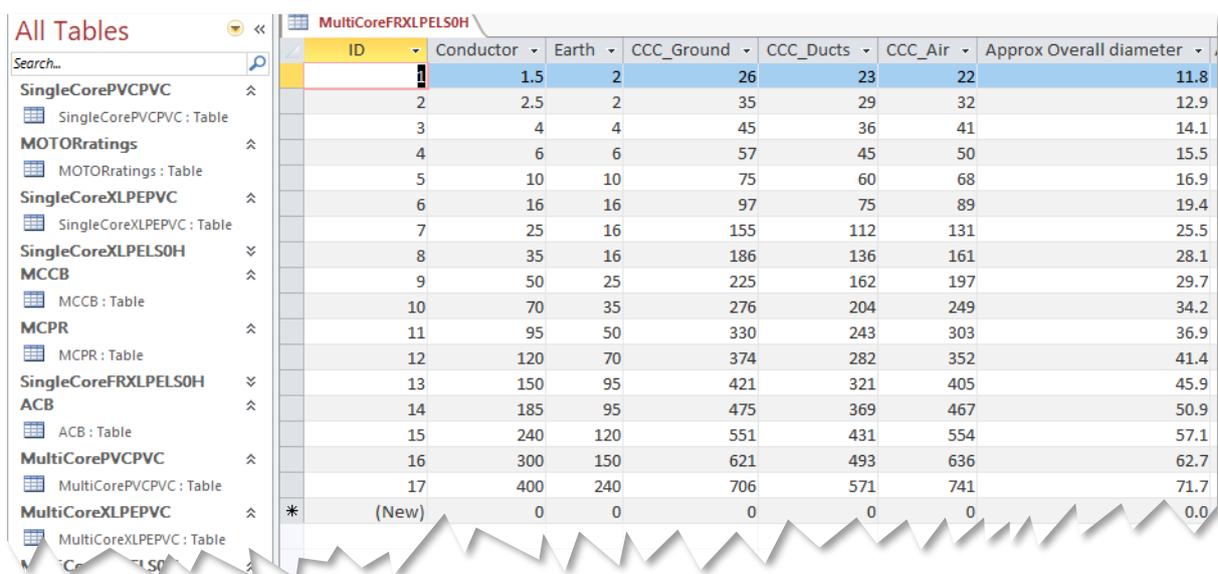
| ID	Conductor	Earth	CCC_Ground	CCC_Ducts	CCC_Air	Approx Overall diameter
1	1.5	2	26	23	22	11.8
2	2.5	2	35	29	32	12.9
3	4	4	45	36	41	14.1
4	6	6	57	45	50	15.5
5	10	10	75	60	68	16.9
6	16	16	97	75	89	19.4
7	25	16	155	112	131	25.5
8	35	16	186	136	161	28.1
9	50	25	225	162	197	29.7
10	70	35	276	204	249	34.2
11	95	50	330	243	303	36.9
12	120	70	374	282	352	41.4
13	150	95	421	321	405	45.9
14	185	95	475	369	467	50.9
15	240	120	551	431	554	57.1
16	300	150	621	493	636	62.7
17	400	240	706	571	741	71.7
(New)	0	0	0	0	0	0.0

Sample database built using Microsoft Access (Fig. 7)

5. Design your interface, shape the user experience

Before rushing to developers for help and thinking of the programming skills needed for such a task, this step is mainly about the engineering part of the interface, and the technical rules governing it.

Many technical considerations should be taken into account while designing your interface. these considerations might include default values for calculation settings, maximum and minimum values for parameters governed by a certain "range" limit (Fig. 8) or cable types available in the cable selection menu.

Many of the decisions taken during the interface design process will have influence on the previous steps, for example, a cable selection menu containing fire rated cable, engineer should be able to view if the load is life safety or not, consequently, Revit family should be planned to include such parameter, etc.
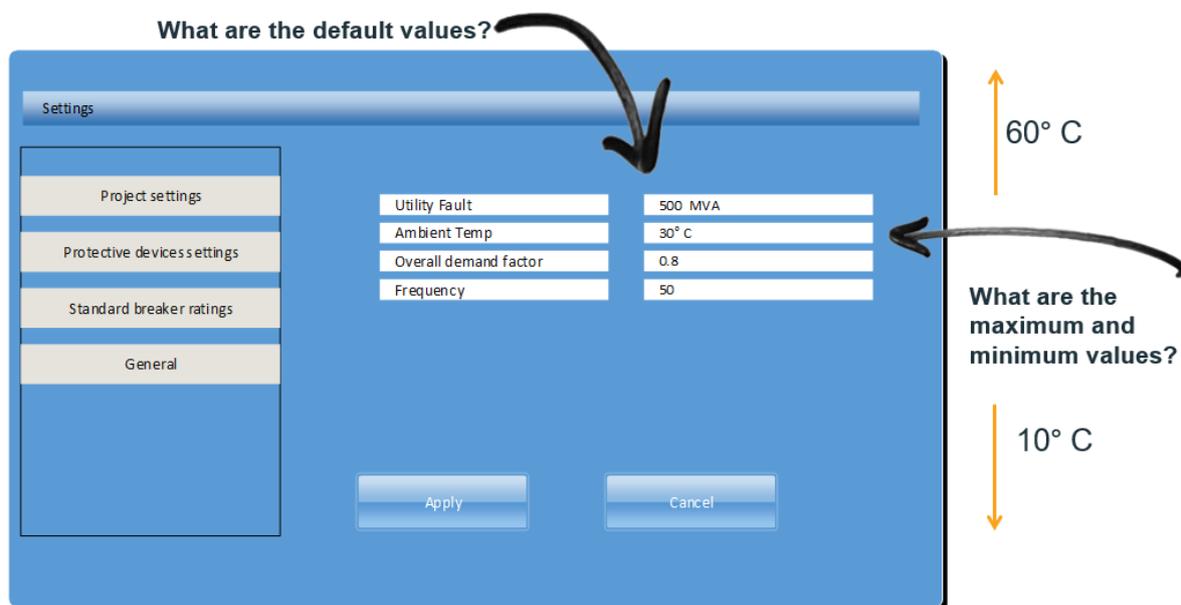
Sample settings interface drawn using Microsoft Visio (Fig. 8)

Revit extensible storage

As each engineering analysis project has its own assumptions and design conditions, one of the main obstacles when embedding electrical analysis in Revit using the API, is storing calculations preferences for each model, if the engineer changes ambient temperature from its default value to another, corresponding to the project's design condition, this value is supposed to remain the same after closing and re-opening Revit file.
The simplest form of such storage is a Revit shared parameter, but this leaves the values prone to human error and unintended change.
Luckily Revit API includes a feature called extensible storage, this feature allows the storage of structured data with multiple fields or properties and their values totally invisible from the user (Fig. 9), moreover, it allows assigning this data to family instances, which might be suitable to store calculation results.

This data is reserved even after Revit file is closed, for more on extensible storage please check helpful resources at the end of this document
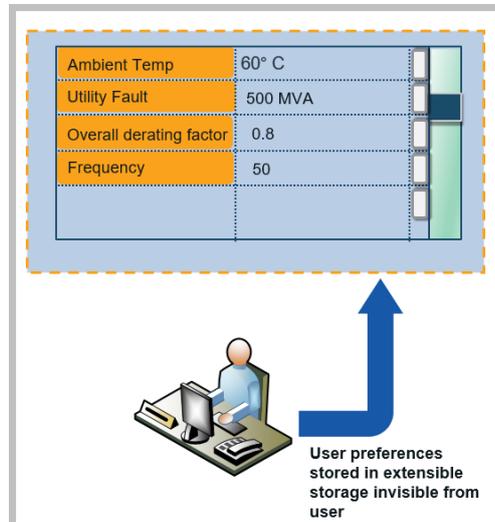

Revit API extensible storage (Fig. 9)

Get acquainted with Revit API key capabilities

At this point, you need to navigate online blogs and SDK samples for code blocks that perform the key functionalities of your analysis solution, whether you need to access data inside Revit or integrate with an external database.

The below are considered key functions when building a solution for most types of electrical analysis (Fig. 10):

- Extract and access data on links (Other disciplines data needed for analysis)
- Extract electrical (MEP) system hierarchy
- Read/Write parameters
- Retrieve/write data from/to external database
- Revit's extensible storage capabilities

By centralizing key functions of your solution and their required code samples, you can avoid a lot of confusion and duplication of effort in the process.
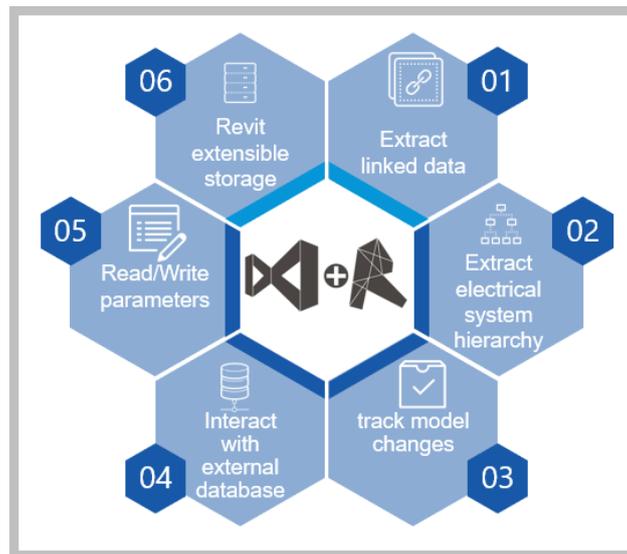
Analysis solution key functions (Fig. 10)

Prepare your code snippets

Start building a code library for each of your solution key functions, since this will make it easier to code complex functionalities and focus coding effort and time.

Conclusion

Through the power of the Revit API, a lot of advanced MEP analysis Can be performed directly inside Revit, resulting in a more connected BIM for MEP workflow, higher accuracy, limited human error, significantly save time and resources moving the MEP disciplines to next level of BIM on the road to full optimization.

Helpful references

Revit extensible storage
https://knowledge.autodesk.com/search-result/caas/CloudHelp/cloudhelp/2016/ENU/Revit-API/files/GUID-113B09CA-DBBB-41A7-8021-005663B267AE-htm.html

http://thebuildingcoder.typepad.com/blog/2011/04/extensible-storage.html

http://thebuildingcoder.typepad.com/blog/2013/05/effortless-extensible-storage.html

Revit MEP API
http://thebuildingcoder.typepad.com/blog/2009/09/the-revit-mep-api.html

Revit API read/write parameters
http://spiderinnet.typepad.com/blog/2011/04/parameter-of-revit-api-8-values-read-and-write.html

Revit API Docs

http://www.revitapidocs.com