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53KMVD
VERSION CREATED ON / VERSION / STATUS
01 Dec 2023 / 1.4 / Approved
EXTERNAL REFERENCE / VERSION

User Manual

Magnetic Field Map Database Query Tool User Manual

This documents describes the Database Query Tool available under https://user.iter.org/default.aspx?uid=85HR3P_v4 and provides basic instructions on its usage, explaining the functions of the user interface elements and the behaviour of the tool itself.

Approval Process			
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Approver	**Schioler T.**	**19 Dec 2023:approved**	**IO/DG/SID/CID/IEA**
Document Security: Non-public - Unclassified *RO: Roccella Riccardo*			
Read Access	**LG: EM Analysis Team, AD: ITER, AD: External Collaborators, AD: IO_Director-General, AD: External Management Advisory Board, AD: IDM_Controller, AD: Auditors, AD: ITER Management Assessor, project administrator, RO, AD: OBS - Remote Handling Section (RHS), AD: OBS - Remote Handling Section (RHS) - E...**		

Change Log			
Magnetic Field Map Database Query Tool User Manual (53KMVD)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v0.0	In Work	31 Jan 2023	
v1.0	In Work	24 Feb 2023	First issue.
v1.1	Revision Required	10 Mar 2023	Updated the reference to the MFM Database Query Tool.
v1.2	In Work	24 Oct 2023	Implemented minor comments from previous version and updated to the latest development of the tool.
v1.3	Revision Required	17 Nov 2023	Implements minor comments from v1.1. Updated to the latest development of the tool, which accounts for the size and local rotation of pieces of equipment. Updated reference to v3 of the Database Query Tool.
v1.4	Approved	01 Dec 2023	Implemented minor comments made on v1.3.

Table of Contents

1 Purpose

The purpose of this document is to describe the Magnetic Field Maps Database Query Tool [1] used to obtain the values of static magnetic field on pieces of equipment at specific locations, size and orientation in the Tokamak Complex.

2 Scope

This document applies to the tool Magnetic Field Maps (MFM) Database Query Tool (DQT) [1].

The tool can be used on any equipment installed in buildings B74, B11 and B14, with the exception of those installed inside the bioshield.

3 Definitions

Abbreviation	**Definition**
DQT	Database Query Took
ETA	Estimated Time of Arrival (or Estimated Time to Completion)
GUI	Graphical User Interface
MFM	Magnetic Field Maps
TKC	Tokamak Complex
VBA	Visual Basic for Applications

4 Interface and usage

4.1 User Interface elements

The user interface is shown in Figure 1 and consists of a single visible worksheet that contains the following elements:

a) A textbox with information text and a reference to this document.
b) A button to start the calculation for the given equipment.
c) A button to copy the entire dataset to the clipboard.
d) A button to clear the dataset.
e) Three checkboxes to activate/deactivate the sources of magnetic field.
f) A selector of the units used to define coordinates and sizes of equipment.
g) A selector of the reference system used to define the equipment coordinates.
h) A table that contains the entire dataset.
i) Top (x-y) schematic view of the TKC.
j) Front (x-z) schematic view of the TKC.
k) Checkboxes to enable labels in the schematics and, when labels are enabled, to switch between showing IDs and Reference names.

The schematic views of the TKC show the midline of the perimeter walls and the walls that separate B74 (on the left) B11 and B74. The bioshield boundary is represented by a blue circle and a blue rectangle in the top and front view of the building, respectively. The orange lines represent the shielded corners, walls and floors levels. Light-blue dots render an approximate schematic of the busbars layout, while red rectangles show the bounding boxes of the Switch Units. These schematics are not intended to provide a precise representation of the TKC. They only serve as a rough guidance to check that the equipment listed in the tool are placed at their expected locations.

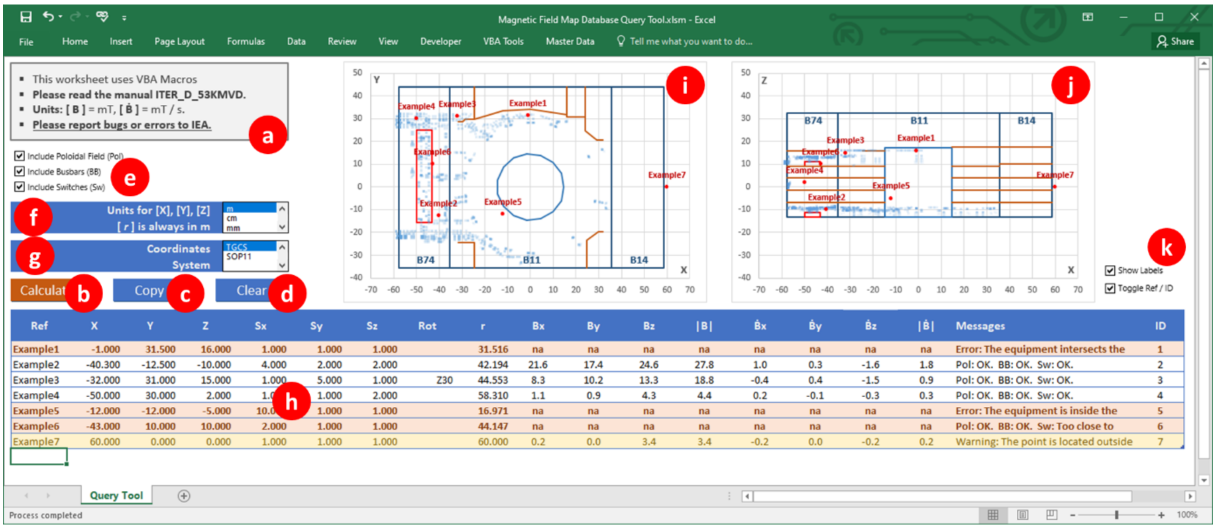

Figure 1 – The user interface of the Database Query Tool. A set of example equipment is defined in the tool to demonstrate possible errors and warnings.

4.2 Usage

The user can select the units (f) for the coordinates and size of the equipment and the applicable coordinate system (g).

By default, the sources of EM field (e) are all active. The user may deactivate one or more sources to check the individual contributions.

The user defines each piece of equipment (objects) in table (h) by providing a Reference name (column `Ref`, for example its functional reference), followed by the centre coordinates (columns `X`, `Y` and `Z`) and the size (columns `Sx`, `Sy` and `Sz`) of its bounding box.

In addition to centre and size, the user can also provide a list of rotations (column `Rot`) to render the actual orientation of objects for which a globally aligned bounding box would provide excessively conservative results.

> *Rotations are given in the format* `<Axis1><Angle1>,<Axis2><Angle2>,...` *For example* `Z10,X45`*.*
> *Angles are in degrees.*
> *The rotations are always intended around the global x,y,z (TGCS).*
> *The rotations are applied in the same order as they are specified and it can be any order that is required to reach the desired alignment.*
> *Zero-degrees rotations are not required:* `Y0,X0,Z30` *is equivalent to* `Z30`*.*

Copy and Paste may be used to define several objects as opposed to entering them one by one.

Objects are added to an existing list by entering them starting at the row right below the table.

No specific limits are set to the number of objects that can be entered. The user shall nevertheless be aware of the impact that a large number of points may have on the total calculation time, which may depend on the hardware used. It is advised that a test run is performed on a reduced list (e.g. maximum 50) to estimate the total required time and then consider running different batches for large lists (e.g. more than 1000 objects).

The centres of the boxes defined in the table are shown on two schematic representations of the building seen from the top (i) and from the front (j), to help the user troubleshoot error messages that may be triggered by invalid coordinates.

The toggles at the right of the schematics (k) enable showing IDs or Reference Names, for better identification of the objects in the charts. Using these options is not recommended when processing large numbers of equipment pieces (e.g. more than 50).

Equipment pieces can be removed by selecting one or more cells in the relative rows, opening the context menu with right-click and then selecting `Delete/Table Rows` (see Figure 2).

The entire list can be cleared by clicking the `Clear` button (d). This action is not reversible.

When the button `Calculate` (b) is pressed, a progress dialog (Figure 3) is shown and the calculation starts. The dialog reports the ETA of the current calculation step and its progress.

The calculation can be stopped at any moment by pressing the `Stop` button on the dialog.

5 Behaviour

The user is not allowed to select any cell other than those in the columns of the equipment definition in the table itself or in the row immediately below it. Whenever any other cell is selected, the selection is moved to the closest selectable cell. This behaviour prevents accidental deletion/modification of the results.

When the definition of a piece of equipment becomes incongruent to the results in the table, the corresponding row is formatted as invalid (grey colour with strikethrough). This can happen for one of the following reasons:

- The equipment is defined, but the calculation was not started, yet.
- The definition of the equipment was modified after running the calculation.
- The selection of applicable sources (e) or the units (f) or the coordinate system (g) was modified after running the calculation.

In the last two cases, reverting the settings to their previous values/selections restores the validity of the data.

At any moment, the cells in the column `Messages` can be clicked to show the full text of the output message.

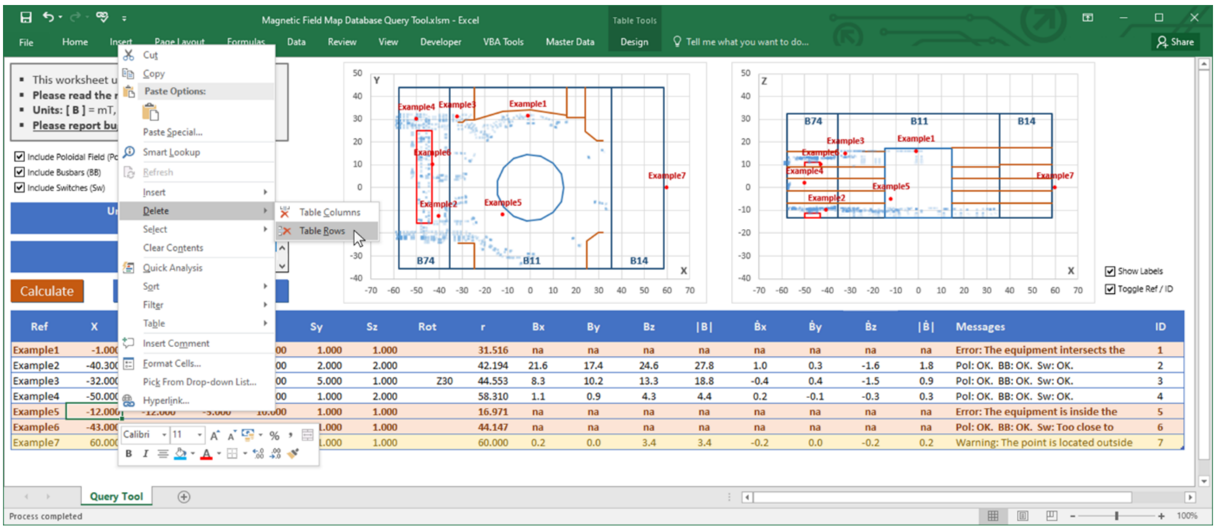

Figure 2 – Equipment definitions are removed using the built-in function in EXCEL that deletes table rows.

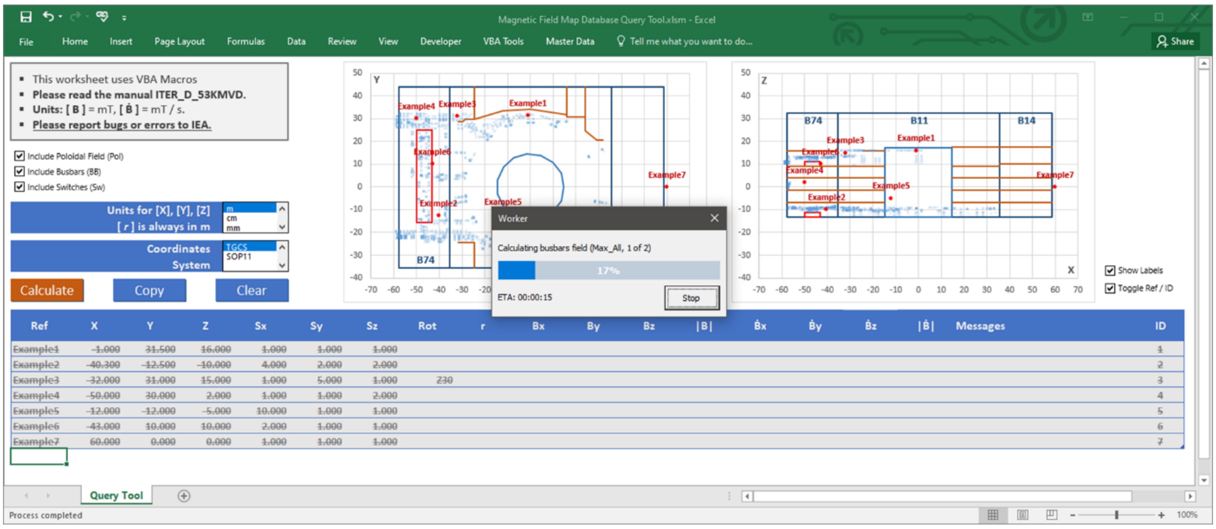

Figure 3 – The dialog window that appears when the calculation starts provide information about the time required to finish the current task and allows stopping the calculation at any moment.

5.1 Results

5.1.1 Calculation

The DQT calculates the total magnetic field as the combination of three contributions:

- Poloidal magnetic field generated by the plasma, CS and PF coils.
- Magnetic field generated by the busbars.
- Magnetic field generated by the switch units.

The first contribution in the list is based on pre-calculated 2-D axisymmetric maps of the field produced by coils and plasma (reported in [2]). The DQT interpolates the values of $\mathbf{B}$ and $\dot{\mathbf{B}}$ from data that are embedded in tabular form in the DQT itself. The interpolation is performed at the eight corners of the bounding box of each object and the maximum of each component is returned.

The second and third contributions in the list are based on the model reported in [3]. The models of busbars and switches are embedded in the DQT and the values of $\mathbf{B}$ are re-calculated each time the `Calculate` button is pressed. By default, the calculation is performed at the eight corners of the bounding box of each object.

Since the field produced by the busbars system is not monotonic, calculating it only at the box corners may be not conservative and therefore the code selects additional points on the box boundary depending on its proximity to the busbars. More specifically, the code selects the points that are the closest to any busbar that is separated from the box by a distance less than twice the largest box dimension. For example: for a box of size 1 × 2 × 3 meters, the tool selects all the busbars within 6 m from the box boundary and searches the point that is the closest to each of these busbars. This is also illustrated in Figure 4, which shows the calculation points used for a relatively large box at close distance from several busbars (the box corresponds to `Example2` in Figure 1).

For each object, the DQT returns the maximum of each field component over the calculation points.

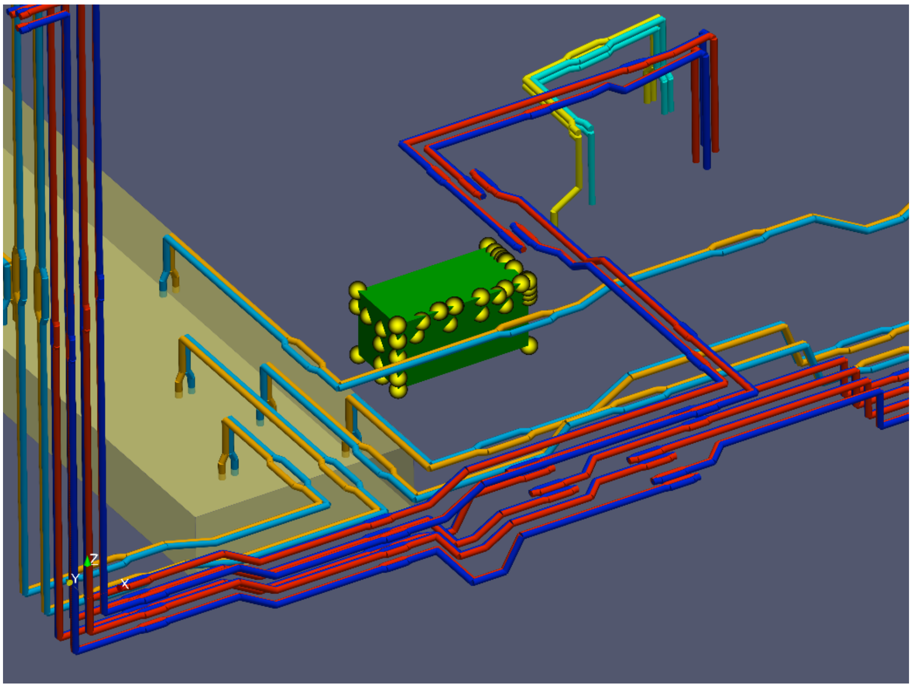

Figure 4 – Calculation points selected by the code on a 4m × 2m × 2m box located in the South-West region of level B2, relatively close to several busbars. All busbars within 8 m from the box faces are considered in the points' selection process.

5.1.2 Combination

Each of the three contributions listed in §5.1.1 has a different nature:

- The poloidal field has cylindrical symmetry and therefore the calculation returns only radial and vertical components.
- The field produced by the busbars consists of 3-D vectors.
- The field produced by the switches consists of a scalar.

The following considerations apply:

- The components of the poloidal field and busbars field calculated internally by the tool can have both negative and positive sign, while the switches field is a positive scalar.
- The values of each component of the poloidal field (including its magnitude) is the peak of that component during the plasma scenario, hence different components are generally extracted at different time steps. This also means that the magnitude of the vector is not equal to the vector sum of the components and therefore it has to be treated as a fourth component.
- For a given *xyz* location in the TKC, the poloidal field can always be converted to a 3-D vector, based on the toroidal location of the calculation point with respect to the plasma centre, while the direction of the switches field is undefined.
- The components of the various contributions cannot be summed algebraically. If two contributions have different sign, they would cancel, but nothing excludes that at a different time step they will actually build up. Therefore, the algebraic sum is not necessarily conservative.

Given the considerations above, the single contributions are combined by first converting the poloidal field into 3-D vectors, then the components of the busbars filed is added arithmetically and then the switches field is added to each component. For a given point $P \equiv (x, y, z)$, being $r = \sqrt{x^2 + y^2}$ its distance from the z-axis, the code will return the total magnetic field as:

$$B_x^{total} = \left|B_r^{pol}\right| \cdot \frac{x}{r} + \left|B_x^{busbars}\right| + B^{switches}$$

$$B_y^{total} = \left|B_r^{pol}\right| \cdot \frac{y}{r} + \left|B_y^{busbars}\right| + B^{switches}$$

$$B_z^{total} = \left|B_z^{pol}\right| + \left|B_z^{busbars}\right| + B^{switches}$$

$$\left|B_{sum}^{total}\right| = \left|B_{sum}^{pol}\right| + \left|\mathbf{B}^{busbars}\right| + B^{switches}$$

In addition to the static magnetic field, the tool also reports its time derivative, of which the poloidal field is the sole contributor, during a disruption:

$$\dot{B}_x = \left|\dot{B}_r^{pol}\right| \cdot \frac{x}{r}$$

$$\dot{B}_y = \left|\dot{B}_r^{pol}\right| \cdot \frac{y}{r}$$

$$\dot{B}_z = \left|\dot{B}_z^{pol}\right|$$

$$\left|\dot{B}_{sum}\right| = \left|\dot{B}_{sum}^{pol}\right|$$

The results of the calculation are reported in the main table (h). The button `Copy` (c) can be clicked to select the table and copy its entire context to the clipboard for further use.

5.1.3 Data Validation

The tool formats the data in the main table according to the validation rules explained in this paragraph.

An object has valid coordinates when the following conditions are met:

- The coordinates of its centre and the three sizes **are valid numeric values**. If any non-numeric text is entered, the values are considered as invalid. If any coordinate is left blank, it is considered invalid. If any size is left blank, it will be considered as zero.
- Any of its calculation points is located inside the volume delimited by $0 < r < 120$ and $-12.9 < z < 59.7$.
- Any of its calculation points **is not located** inside the bioshield, which is the region limited by $r < 14.7$ and $z < 17.1$, where r and z are the radial and vertical coordinates with respect to TGCS.
- Any of the calculation points **is not closer** than 0.2 m from any busbar or switch complex unit.
- The box faces **do not intersect** any busbar.

If any of the object's calculation points has invalid coordinates, the string `na` is returned over the entire row and an error will be prompted in the remarks.

A minimum size of 0.1 m is required for any equipment. The calculation will be based either on the sizes defined by the user or the minimum required size, depending on which is the largest. A warning will be prompted in the remarks whenever one or more size components do not respect the minimum requirement. Since blanks in the size components are considered as zeros, they will also be considered as the minimum required size.

The constraints given above allow querying the magnetic field also at locations that are outside of the TKC (e.g. up to $r = 120$ m), in which case the DQT will return valid results and a warning will be returned in the remarks.

When the tool returns an error or warning, the corresponding line will be formatted as red or yellow, respectively. In this case, the user shall first check the correctness of its coordinates. If the definition of the equipment is correct, one of the following cases will apply:

- The equipment is outside the domain of the TKC: the EM Field Maps are not applicable.
- The equipment is inside the bioshield or too close (< 0.2 m) to busbars or switches, in which case dedicated analyses will be required to produce an accurate evaluation of the applicable magnetic field.

6 References

[1] Magnetic Field Map Database Query Tool (85HR3P_v4)

[2] Calculation of the Static and Transient Magnetic Field produced by Plasma, CS and PF coils (XEN5S5 v3.7)

[3] Calculation of the Magnetic Field Produced by Busbars and Switches in the Tokamak Complex (4FYHNR v1.5)