Smart Torque Calibration Automation

Stephen Ng Sze Joo, Calibration Department

I. INTRODUCTION

As the torque calibration process has been automated within the form of the Torque Calibration Module the entire calibration process cycle time has been greatly reduced (estimated to be around 50%). However, the Calibration Department Sapphire team faces certain challenges as the module within the SAPPHIRE system has compatibility issues with an older torque metre (CEDAR) and can only accommodate the HIOS torque metre. By having a solution that accommodates this additional metre, through an offline solution would open up the facilities for the “automation” of the torque calibration process to the CEDAR torque metre. Additionally, there are dead-wifi spots throughout the facility which makes it such that the calibration engineers are not able to load the pending calibration tasks and perform calibration offline. Lastly, there is a potential to market the Smart Torque Automation solution externally apart from the SAPPHIRE system.

II. Background

SAPPHIRE System is the web application that houses modules which are used within the calibration process which was developed and actively maintained by the Calibration Department Sapphire team. The end users of this system are associate engineers, managers, supervisors, equipment owners who will manage the calibration service request, calibration tracking, and equipment status of the entire calibration process of the web application. The user's laptop needs to be linked to a LAN or Wi-Fi network and the Keysight VPN (Virtual Private Network) before they can access the SAPPHIRE System.

Torque calibration is the process of testing and adjusting the accuracy of a torque measuring or applying device, such as a torque metre or torque tool. In order to ensure accuracy in a variety of applications, from manufacturing to automotive maintenance, a torque metre is a tool that measures and displays the amount of rotational force or torque imparted to an item. In contrast, a torque tool is a device that is used to impart a precise amount of torque to fasteners. This ensures that the fasteners are tightened to the exact specifications, which is essential for product quality and safety in industries such as construction and assembly. By maintaining quality and safety requirements, calibration guarantees that these instruments offer precise and dependable torque readings or applications.

Smart Torque Calibration module, refers to the module which houses the entirety of the torque automation process from the form which is used to store the calibration task details and the records as well as the Certificate of Calibration and generation of the measurement report.

III. Problem Statement

This project’s inception is due to the following problem statements:

1. Without the Sapphire System, calibration cannot be recorded (without WIFI).

2. Standalone Smart Torque Calibration Automation without Sapphire System.

3. The present online Sapphire system module and the CEDAR Torque Metre are unable to communicate.

As previously mentioned, there are dead spots within the facility which makes it such that the calibration engineers are not able to use the Sapphire system (as they will need WIFI connectivity to do so). Hence, they are not able to pull a task list from the Sapphire database as well as perform the calibration tasks.

The potential to introduce this Smart Torque

Calibration Module to other sites as well as external clients poses a problem as it is linked to the Sapphire system which requires a dedicated developer team as well as the Microsoft SQL Server which requires licensing.

Lastly, the issue whereby security concerns of the CEDAR torque metre which uses Dynamic Linked Library (DLL) which does not allow the web applications to read values from the metre excludes the usage of the given torque metre.

All these problems can be addressed via a single solution that is a Windows based Desktop application such that the pending calibration tasks can be pulled from the network database to be saved within the local database which enables calibration records to be viewed and altered offline. Besides, a calibration report from a completed calibration can be generated locally and calibration details can be uploaded to Sapphire database and the calibration form can be populated automatically. Externally, calibration engineers can fill in the details into the calibration form manually and the details are saved locally and the report can be generated from completed calibrations. The application supports the DLL interface enabling the application to communicate with the torque metre.

IV. Design and Implementation

A. Database Design

To house the calibration details and records, we design a local database modelled after the SAPPHIRE (for live production) and SAPPHIRE_NET (for testing purpose) databases created and stored in the Microsoft SQL Server Management Studio whereas the local database will be housed within the MySQL Workbench with MySQL Server.

Tables involved in the operations within SAPPHIRE database:

1. db.SAPPHIRE.torq_measure
2. db.SAPPHIRE.torq_measure_details
3. db.SAPPHIRE.torq_target
4. db.SAPPHIRE.torq_threshold

Tables created in SAPPHIRE_NET database:

1. db. SAPPHIRE_NET.torq_measure
2. db. SAPPHIRE_NET.torq_measure_details
3. db. SAPPHIRE_NET.torq_target
4. db. SAPPHIRE_NET.torq_threshold

Below are the newly created tables within the local MySQL database.

1) users

This table holds the users information for Non-Sapphire users.

Column Name	**Data Type**	**Column Description**
UserID	int	Users' unique ID.
Username	varchar(140)	The prefix of the user's email before the "@" symbol.
Company	varchar(140)	The suffix of the user's email after the "@" symbol.
Password	varchar(140)	User's password stored as a hash of SHA256.

2) caldata

Every form saved within the application is contained in this table, which also includes the form header. Each column corresponds to a necessary item for the calibration process.

Column Name	Data Type	Column Description
FormID	varchar(255)	Unique ID for calibration data forms.
EquipID	varchar(255)	The equipment ID of the torque related to the calibration referenced by the form ID.
TorqCalID	varchar(255)	The torque calibrator ID that is related to the calibration referenced by the form ID.
TorqSet	decimal(10,0)	The torque value in Newton-meter value (Nm).
StartCalDate	datetime	Start date of calibration.
Location	varchar(255)	Location where calibration was performed.
DoneBy	varchar(140)	Username of the user who completed the calibration.
TrackingID	VARCHAR(255)	Tracking ID that is unique to the

		current calibration job.
Complete	int	Flag indicating if calibration is completed.
Submitted	int	Flag indicating if calibration is submitted.

3) readdata

This table contains the form body's data, which consists of the readings from the pre- and post-calibration procedures. The FormID column in the caldata table connects the readings to the form header.

Column Name	Data Type	Column Description
ReadIndex	int	Unique identifier for each reading.
FormID	varchar(50)	Form ID associated with the reading.
ReadVal	decimal(10,2)	Actual reading value.
Deviation	decimal(10,2)	Deviation from the desired value.
Status	varchar(50)	Status of the reading.
DesVal	decimal(10,2)	Desired (target) value.
IsPreCal	int	Flag indicating if the reading is from a pre-calibration.
TrackingID	VARCHAR(255)	Tracking ID associated with the reading.

4) torqequip

The table contains the details of every piece of torque equipment, including its ID, description, and tracking ID for the associated job.

Column Name	Data Type	Column Description
Index	int	Unique identifier for torque equipment.
TorqCalID	varchar(255)	Torque Calibration ID associated with the equipment.

TorqCalDesc	varchar(255)	Description of the torque equipment.
TrackingID	VARCHAR(255)	Tracking ID associated with the torque equipment.

5) tracking_source

These tables contain the pending tasks that are copied over from the Sapphire System database locally during the process of cloning over the pending jobs, enabling the data of the pending tasks to be loaded upon selection.

Column Name	Data Type	Column Description
EquipmentID	VARCHAR(255)	Equipment ID.
ModelID	VARCHAR(255)	Model ID of the equipment.
SerialNumber	VARCHAR(255)	Serial number of the equipment.
ServiceID	VARCHAR(255)	Service ID associated with the equipment.
PL	VARCHAR(255)	PL (Product Line) information.
Dept	VARCHAR(255)	Department information.
DueDate	DATE	Due date for the equipment.
TrackingID	VARCHAR(255)	Tracking ID associated with the equipment.
TorqueSet	decimal(10,0)	Set torque value for the equipment.
Status	VARCHAR(255)	Status of the equipment.
SapphireFormID	VARCHAR(255)	Sapphire Form ID associated with the equipment.

B. *Implementation*

Several features are required within the application:

1. Login and Registration Page
2. Torque Calibration Measurement Module
3. Maintenance modules
   a. Equipment
   b. Threshold
4. Sapphire Database Pending Tasklist

1) *Login and Registration Page*

This security feature authenticates both Keysight and Non-Keysight users. For internal users, their details via their UserNT and Keysight password are able to be authenticated via the LDAP (Lightweight Directory Access Protocol) which communicates with the company's server. For Non-Keysight users, they will have to register their details, that is their email and a password which will be saved within the local database (passwords stored as SHA-256 hashes) which then they can be authenticated using their email and password. The selection is explicit via the selection of radio buttons.

2) *Torque Calibration Measurement Module*

This is the primary module enabling the user to record down the details of the calibration such as the torque setting, torq threshold setting, location and the readings for the pre-calibration and post-calibration stages refer to Figure 1.

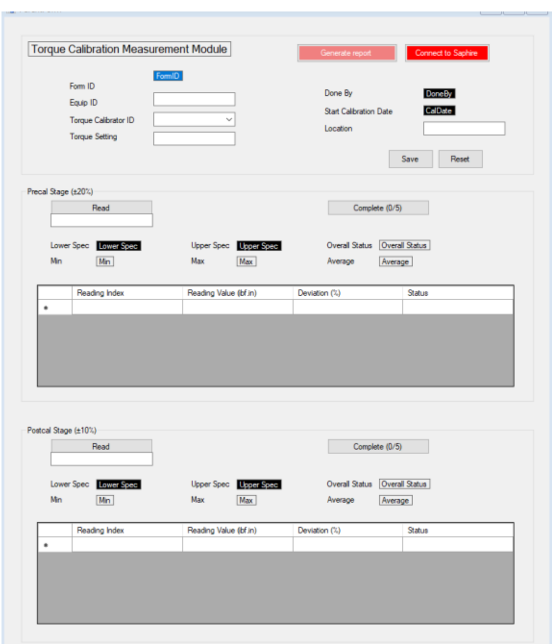

Fig. 1: User Interface of Torque Calibration Measurement Module.

If the user wants to manually fill in details of a calibration they can select the "Torque Calibration Measurement" side tab. Then, they can select which torque metre they would want to use whether that be the CEDAR or HIOS torque metres. Then they can proceed with the calibration process.

The calibration process is broken down into the filling of the form header, the pre-cal; and post-cal process. Firstly, they have to fill in the details into the form header refer to Figure 2. On save, the details will be stored within the local database. Next, they will perform five torque measurements whereby if any of the measurements exceed the upper or lower threshold of the post-cal torque setting, the user will have to complete the post-cal stage to complete the calibration task or else the task will be considered completed at the pre-cal stage.

Once the calibration is completed the user can either generate a local measurement report whereby the user will be prompted to save the pdf to a local storage location or else the user can submit the form to Sapphire via the "Upload to Sapphire" button.

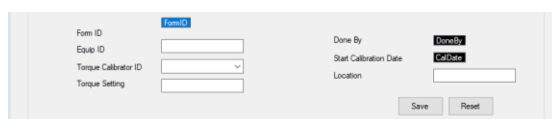

Fig. 2: User Interface of Torque Calibration Measurement Module Form Header.

3) *Maintenance modules*

There are certain values that are constants within the application such as the threshold percentage for the pre-cal and post-cal stages and the equipment and details list which are stored within the local MySQL database.

Users do not have to edit and update the values manually via SQL queries. Instead by selecting the respective maintenance modules side tabs they can change the values via text boxes, refer to Figure 3 and 4 which then will be automatically reflected within the local database and subsequently the application,

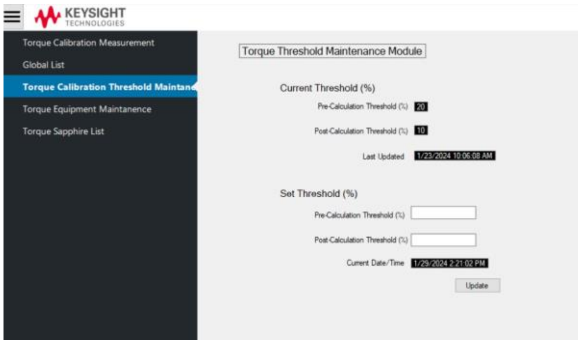

Fig. 3: User Interface of Torque Calibration Threshold Maintenance Module.

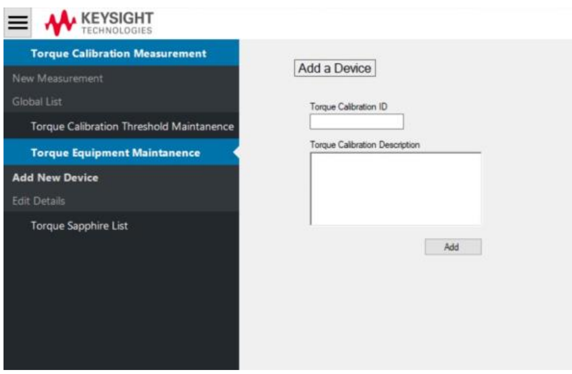

Fig. 4: User Interface of Torque Calibration Equipment Maintanence Module.

4) Sapphire CEDAR module

Currently there is only a module for the HIOS torque model, there needs to be another module (similar to the form which we use to perform the calibration but on Sapphire), this is such that when we upload the data from the desktop application to the Sapphire database, the data can be reflected onto the Sapphire website and the user can generate a Certificate of Calibration.

Based on the .aspx file we modified the page to accept the CEDAR data, and also we have formed a url generator within the application such that the parameters of the url query are able to retrieve the corresponding data of the calibration. This url generator will automatically generate the link which will pop-up and direct the user to Sapphire with the corresponding calibration data when the “Connect to Sapphire” button is clicked.

5) Sapphire Database Pending Tasklist

There is an option whereby when the user is connected to the internet they are able to access the list of pending calibration tasks within the Sapphire database by clicking on the Torque Sapphire List side tab. This enables the user to use checkboxes to select the tasks that they want to import over to their local database and by clicking select the tasks and their details will be moved over to the Existing Form tab within the page refer to Figure 5. Within the Existing Form tab the user can start a new calibration or continue with their task by clicking on the “Select” button of the corresponding tasks refer to Figure 6. Once selected the details of the form header will be auto-filled based on the imported parameters.

On the contrary, all the calibration tasks can be viewed via the Global List which contains all the calibration tasks which have been started within the application refer to Figure 7. Users are able to return to a given calibration to complete the calibration or to generate a report.

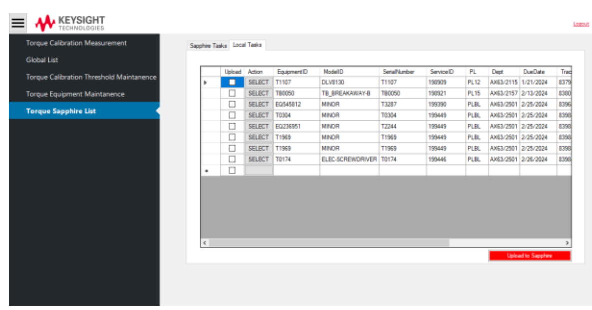

Fig. 5: User Interface of the Existing Form tab within the Torque Sapphire List sidetab.

Upload	Action	EquipmentID	ModelID	SerialNumb
☐	SELECT	T1107	DLV8130	T1107
☐	SELECT	TB0050	TB_BREAKAWAY-B	TB0050
☐	SELECT	EQ545812	MINOR	T3287
☐	SELECT	T0304	MINOR	T0304
☐	SELECT	EQ236951	MINOR	T2244
☐	SELECT	T1969	MINOR	T1969
☐	SELECT	T1969	MINOR	T1969
☐	SELECT	T0174	ELEC-SCREWDRIVER	T0174
☐				

Fig. 6: "Select" buttons and each of their corresponding tasks.

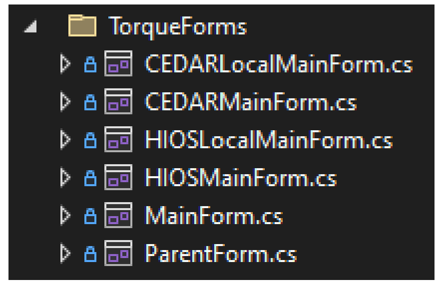

Fig. 8: The different parent and children forms within the application.

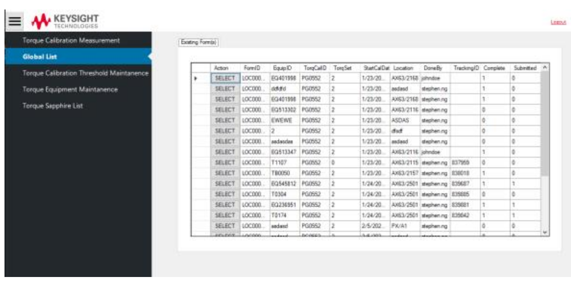

Fig. 7: User Interface of the Global List which contains all the calibration tasks which have been started within the application.

V. Challenges & Solutions

1) Issue whereby the different torque metres require different forms however similar logic, however Windows Form applications do not allow the designer page of a form to be inherited together with the page.

This issue makes it such that we are required to have a master form whereby we inherit this form to have 2 child forms which run using the similar logic to the parent form but having different ways to read the values from the given metres, refer to Figure 8. For the CEDAR metre the way to read the values from the page is by using the DLL previously mentioned whereas the HIOS metre directly writes the value from the metre when the values are cleared straight to the location of the cursor. Despite not having access to the designer, the page design is completely inherited which means we can reference to the elements such as text boxes or buttons within the child for, refer to Figure 9.

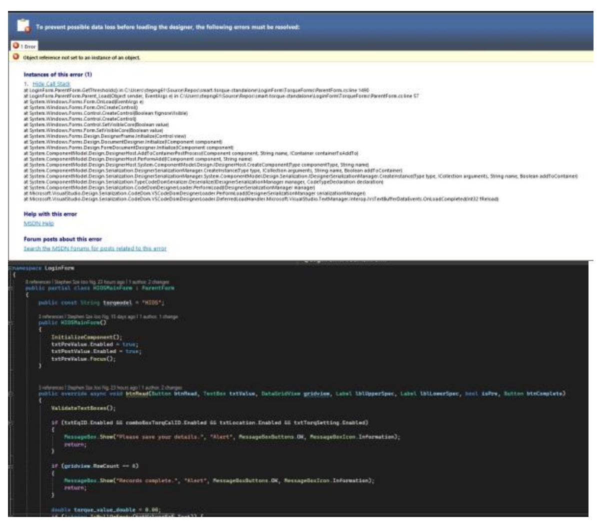

Fig. 9: Error code obtained when trying to open the designer file of the parent form. However, the code can be successfully overridden in the child classes.

2) The sidebar component needs to be accommodated for maintainability and scalability.

The sidebar if built from scratch might have issues to accommodate new menu items. Instead, we opted to purpose a NuGet package that is the Z80NavigationBar which is open-source and free in the form of a navigation tree structure similar to the one found on the Sapphire website, refer to Figure 10. The code structure and the syntax allow the realisation of children nodes by an iteration control structure to retrieve the parent and child menu items.

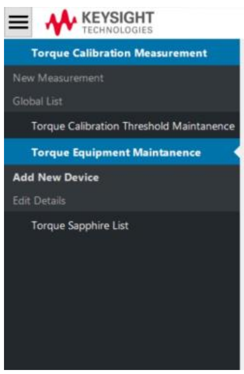

Fig. 10: User Interface of the sidebar with navigation tree structure.

3) Popup Installer Solution for MySQL Server and MySQL Workbench Integration whereby Initial, Silent Installation option is not a viable option.

The initial plan was to use the MySQL Installer command line to perform silent installation of MySQL Server and MySQL Workbench. However, there is a limitation in this approach. The MySQL Installer command lines are hidden during execution, making it difficult to track and ensure that the installation process is completed successfully and only available in the MySQL Enterprise installer.

To overcome this obstacle, a different solution is used: implementing a Popup Installer using a bundled approach. This method entails the user-friendly interface of the installer with a user manual that walks users through the installation process. The bundled solution would include the required MSI files to ensure a smooth integration with our application such that the installer will only pop up if the application is not already installed.

4) Loading data from already partial/complete forms.

This task proved challenging as it revolved around loading data from the local MySQL database and dynamically populating various forms based on specific conditions. The first condition involves forms that only load header details, such as torque settings, equipment ID imported from Sapphire, and the indication that the form is not yet started. The second condition arises when a form is already in the calibration process, and either pre-calibration with or without post-calibration has been completed. Managing these conditions is particularly challenging due to each form having its own logic for buttons. It's crucial to ensure that the correct buttons are disabled during data loading, preventing the accidental overwriting of previous data and ensuring that data is not submitted to Sapphire more than once. Striking the right balance and synchronising the form's internal logic with the loaded data conditions is key to maintaining the integrity of the calibration process.

VI. Completed Solution

A. Offline Smart Torque Calibration Application.

The proposed standalone Windows-based operating system application aims to address three key challenges in the Smart Torque Calibration module within the Sapphire system. Firstly, calibration engineers can utilise the application to pull the pending calibration list from the Sapphire system database and execute calibration tasks offline. This ensures that the calibration process remains uninterrupted even in locations without internet connectivity. The application is designed to save all calibration records within a local MySQL database during offline operations, promoting data integrity, refer to Figure 10 for the overall workflow.

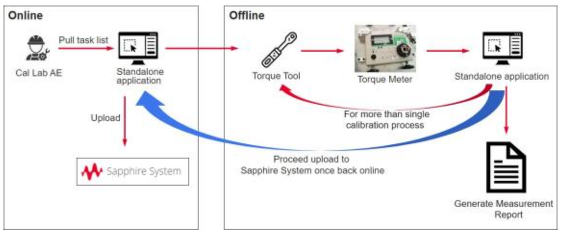

Fig. 10: Overall visualisation of the Offline Smart Torque Calibration Application workflow.

B. External User Functionality:

For external users not within Keysight, the application offers a seamless solution. These users can log in, perform calibration tasks, and save the calibration results directly onto the local MySQL database. The ability to generate PDF reports locally enhances flexibility and autonomy for external users, allowing them to maintain detailed records independent of Keysight's network, refer to Figure 11 for the overall workflow.

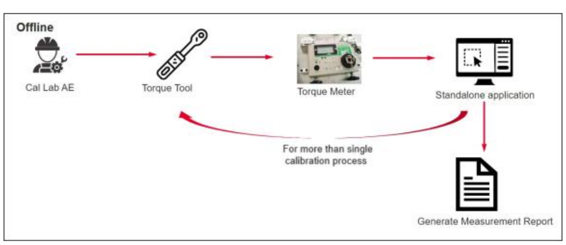

Fig. 11: Overall visualisation of the Standalone External Solution Section of the Applications' workflow.

C. CEDAR Torque Metre Compatibility:

One of the notable challenges addressed by the application is the compatibility with CEDAR torque metres. Since the application is not web-based, it aligns with the security requirements of the CEDAR device. This allows the application to read and save readings from the CEDAR torque metre effectively. The solution ensures that calibration engineers can work with a variety of torque metres, providing a versatile and inclusive approach to the calibration process.

In summary, the proposed application offers a comprehensive solution, enabling offline calibration, empowering external users, and ensuring compatibility with the CEDAR torque metre, thereby enhancing the efficiency and flexibility of the Smart Torque Calibration module within the Sapphire system.

VII. FORESEEABLE UPDATES

A. Siloing of Sapphire and Non-Sapphire features.

In the context of torque management systems, user silos are created by segregating access and visibility based on user classifications. Sapphire users have complete access and visibility to the torque management system's entire range of functionalities and data. This includes unrestricted access to the Torque Sapphire list, which offers detailed information and control over torque-related operations and resources. Non-Sapphire users, who may include general staff or individuals with restricted roles, have intentionally limited access and visibility within the system. This restriction extends to the Torque Sapphire list, where non-Sapphire users are either completely barred from accessing the list or are granted only partial visibility restricting their ability to view or manipulate torque-related data of the Sapphire database.

B. Manual filling of calibration task with compatibility with Sapphire

The manual filling of calibration tasks, currently exclusive to non-Sapphire users, is poised for future enhancements through the implementation of context matching. As part of this evolution, calibration engineers will gain the capability to manually input calibration data and subsequently upload it to Sapphire, expanding the ability of users to contribute to the calibration process. During the upload process, a context matching mechanism will be introduced to enable engineers to handle conflicts that may arise between the manually inputted data and existing records in the database. This advanced feature serves to identify potential discrepancies, such as typos or conflicting upload statuses, and empowers calibration engineers to resolve these conflicts effectively.

By incorporating context matching into the calibration data upload workflow, we can enhance the accuracy and reliability of the data stored in Sapphire, fostering a collaborative environment where calibration tasks are seamlessly managed, and data integrity is prioritised. This forward-looking approach not only broadens user accessibility to calibration functionalities but also establishes a robust framework for maintaining high-quality calibration records within the Sapphire platform.

C. Edit, sort, search and hide specific calibration tasks.

The Torque Sapphire list should include advanced features that will allow users, particularly calibration engineers, to seamlessly edit, sort, and selectively hide specific calibration tasks. This enhancement is intended to streamline user workflows, ensuring easy access and effective task management. Calibration engineers will be able to edit incorrect header details. The addition of sorting capabilities will increase efficiency by allowing users to organise tasks based on relevant parameters such as priority or due date. Furthermore, the ability to selectively hide specific tasks creates a personalised user experience, allowing engineers to focus on relevant information without distraction. This feature set not only simplifies task management but also helps to create a more intuitive anduser-friendly interface.

VIII. Conclusion

The Smart Torque Calibration Automation Standalone and non-WIFI tethered Desktop Application represents a significant step forward in addressing key challenges within the Sapphire system's Smart Torque Calibration module. This standalone Windows-based application offers a comprehensive solution with a wide range of features.

In summary, this application acts as a one-stop solution, enhancing efficiency and flexibility of the Smart Torque Calibration process and its seamless integration with the Sapphire system. The Offline Smart Torque Calibration Application stands out for its ability to deliver a subset of the functionalities offered by the Sapphire system, even in offline mode, ensuring that calibration processes remain unhindered in locations with limited or no internet access.

Also, its capability to support both the HIOS and CEDAR torque metres collectively position it as a robust and versatile tool. Looking into what is to come, the current modular architecture of the application allows for potential accommodation of additional modules in the future, demonstrating its scalability and adaptability for evolving calibration requirements.