Automation of WHMI for the Functionality Analysis of the IED using Robot Framework

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***Abstract*- An electrical substation refers to a station of power generation, transmission and distribution systems where voltage is transformed either from high to low or from low to high using step-down and step-up transformers respectively. Substation automation means utilizing the data from the Intelligent Electronic Devices (IED's) for the control and automation functionalities inside the substation, based on the control commands that it receives from remote users to control power system devices. The end user's control the devices by the applications. These applications will have to undergo many tests to achieve more productivity. WHMI is one such web application which can be used to check the functionality of the IED using the web. WHMI automation is used to automate the continuous testing tasks of the WHMI application which is hard to do manually. To perform the automation a free-ware open source Robot Framework tool is used which uses the python coding. This technique is based upon finding for keywords in the test suite that describes actions to be performed on the target and calling functions associated with those keywords. Using keyword-driven approach, reusability of automated test cases can be improved. The effectiveness and efficiency of testing can be increased with the help of test automation. The results are compared with manual testing and the performance is analyzed.**

Keywords—Protection and Control IED manager (PCM), Intelligent Electrical Device (IED), Web Human Machine Interface (WHMI) and Robot Framework.

I. INTRODUCTION

IED (Intelligent Electronic Device) are the devices standard in new or redesigned integrated substation protection, monitoring and control systems. IED's are used in the substation to control and monitor the complex electric systems by communicating with other IED's within the substation. Protective IEDs are complex and multifunctional which are intended to protect substation equipments and the electric power systems from the effects of various abnormal system conditions. The proper testing of these protection IEDs that are being used in a substation automation system must be done and this is possible only when there is good understanding of its functionality. Understanding its functionality includes along with the basic protection functions also the built in and user programmable schemes. These multifunctional protection IEDs used in a substation automation system we also need to consider their non-protection functions, such as Measurements, Control, Monitoring, Disturbance recording and Event recorders.

In substation a Station Bus is used for IED to IED communications within the substation, and also for the interface between the IEDs and the substation level HMI. [1] Use of IED's in the substation avoids the usage of copper control cables and permits the usage of fiber to bring out the improvements in the functionality and reduction of engineering, commissioning and maintenance costs. The receiving devices then process the information, make decisions based on the data and take action based on their functions. The work of the protection and control devices in the substation in this case will be to operate their relay outputs or to send a high speed communication GOOSE message to other IEDs in the substation to trip a circuit breaker or initiate some or the other control actions. PCM application is used for various tasks in the IED engineering. WHMI enables the user to access the IED via the web browser. But when no engineering tasks is required and to perform supervision of events generated, setting groups, disturbance handling etc.. WHMI is sufficient. The problem scenario of the project is that it takes more time and resources when this is performed manually. Hence automation of WHMI is performed to test the devices and to perform read and write the parameter to IED and to achieve end to end execution. Therefore the paper proposes the automation of the WHMI for the functionality checking of the IED.

A. IED basic working

The input signal sent to the Analog-digital converter, converts the analog input to digital input. From there a part goes to protection unit and another part to measurement unit as shown in Figure1. In measurement unit it measures the voltage, current and so on. In protection unit it continuously analyzes whether there is an increase in the voltage or current, or any abnormal sudden action that can be checked. If there is any abnormal condition like that, then the protection unit triggers the switch which activate and breakdown the breaker, that's how the protection is done in IED's.

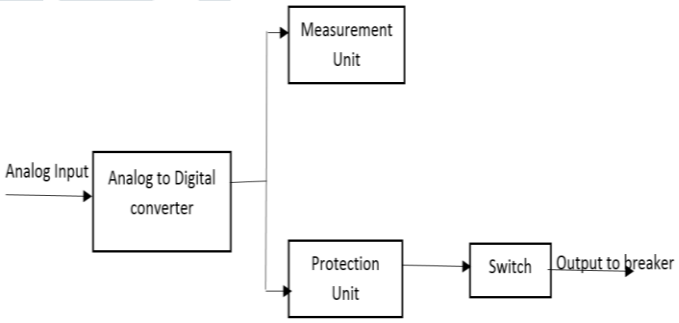

Figure 1. IED working flow chart

B. Test Automation

Software testing is a method or a testing process directed to provide the stakeholders a guarantee about the quality of the software product or the system which is under test. It likewise also provides an independent view of the software and provides the business stakeholders to appreciate the software application and to understand the risks of its implementation. Testing methods includes implementing the software program or the application with an intention of finding the software bugs and verifying whether the software application is fit for use and reproducing the bug to treat with that unexpected behavior. Testing can be done in two ways, Manual and

Automation. While testing manually a software has to be tested each function by function individually without using any automation tool. The tester has to take the role of end user and test the software application to identify any software bug. But in case of automation this functionality checking can be done by using the automation tool. Automation testing includes the test scripts that can re-execute several times the test scenarios quickly, and repeatedly that were performed manually. Using Test automation, once the test cases are automated they can be frequently used to achieve end to end execution. Practically it is not possible to automate everything.

C. *Protection and Control IED Manager*

Protection and Control IED Manager (PCM) offers all the necessary functionality to work throughout all stages of the IED life cycle such as planning, commissioning, engineering, operation and disturbance handling and functional analysis. It is compliant with IEC 61850. The topology in the PCM will allows you to view and edit the information about your power systems. It has configuration and communication management tool which provides efficient functionality for application configuration and communication engineering. It enables easy to use capabilities for I/O and signal mapping. For the smooth integration between PCM tools and IED's, the user interface, workflow and IEC 61850 based data model in PCM is designed similar to the IED itself. Test Complete (version 12) tool as an area or a workplace where the codes are written to create a user of the IED using the PCM. The user thus created can login to the IED through the WHMI using the login password created through PCM.

D. *Robot Fraework*

Robot Framework is a python based keyword driven approach test automation framework used for acceptance testing. This framework includes tabular syntax which provides easy use for creating the test cases in the uniform way. Test cases are generated as keywords parallelly generating an ability for the reusable of the keywords. This generates the result reports and logs in HTML format in a user-readable way. Selenium is an open source functional automation tool for the web based application. Robot Framework import the selenium library to support web application testing. This was developed by the "Thought Work" in 2004. It is highly recommended and is a remarkable tool for functional software testing. A Human-Machine Interface (HMI) connects a person to a machine, system, or device. It is like a user interface. Each time instead of going near IED and making changes we can operate the device using Web HMI and also we can change the parameters accordingly.

II. RELATED WORKS

In the previous work by Leckraj Nagowah and Purman and Roopnah [2] in " An Approach to Testing Web Applications On the Fly" has proposed that a conformance testing approach for web based applications. The software testing method he used is based on Aspect oriented Programming approach. It increases the modularity of the code at the same time code becomes lengthy. In this paper he has given the description of various types of software testing and giving reasons in support of use of AOP for testing. It provides the concise outline of the related works in the direction of software testing using AOP and explain the difference of these works. A. Ieshin, M. Gerenko, and V. Dmitriev[3] in "Test Automation and Flexible Way" has worked to increase the performance of the system which is under test. This includes a human operator as trained, semi-automatic system testing process via a human machine interface. Using Robot Framework the human intervention is not required and the system under test can be completely automated.

Breno Jácomo and de Freitas [4] in "Preventive actions in protection relays network using SNMP", has proposed that the information in the IED has to be taken from the operator and maintenance team to take further providences. By using this intrinsic information it is possible to take some preventive actions from the maintenance team recovery the power system and improve the availability of power system. On receiving the intrinsic information of the power system, the HMI can generate alarms for maintenance team to alert them. For example, if there is any exchange of erroneous message between the IED's, if any datagrams were lost, if frames discarded will generates the alarms. This information can help the maintenance team to take actions. In "Exploring the Use of Test Automation Framework" [5] Alex Cerv Antes used an approach in which initially the tester is supposed to choose, prioritize ad perform the relevant test cases manually. During the manual testing all the field data is gathered and analyzed. Based on these data an automation test cases are designed. In [6] "Value Based Software Engineering- Overview and Agenda" Boehm B and Biffl S proposed an automation test approach for distributed system. Initially the system under test is validated. Based on the validation results the testing approach is designed based on the automatic testing framework. Actual examples has been considerd to prove test automation is efficient. Ramler R., Biffl S., Grünbacher P [7] has discussed the test automation problems. And he has concluded that the keyword-based approach in the automation is significant improvement over record/playback. He has also analysed that keyword-driven test automation requires programming skills and it will have the lesser test scripts and less maintenance of test scripts. All the necessary information regarding the usage of Robot Framework and importing the libraries and the usage of the API's is referred from the robot Framework website. [8]

III. METHODOLOGY

Substation Automation have a hardware architecture that includes analog and binary input modules and relay outputs. The processing module in the IED process the data and activate the relay outputs. The IED's operate their outputs and are carried within the substation IED's using GOOSE communication in order to trip a breaker or to initiate some other control actions. Figure.2 shows the architecture diagram of the proposed method. PCM is the testing application which is used to create a user for the WHMI. Connectivity Packages are the software executable codes helps system tool to communicate with IED. Communication has to be set up between PCM and an IED. It takes two ways, either using direct point to point link between PCM and the IED front port or indirect link through station LAN or from remote via network. User for the IED has to be created using a PCM application. In the proposed method test cases are

designed to automate the web application WHMI to check the functionality of the IED.

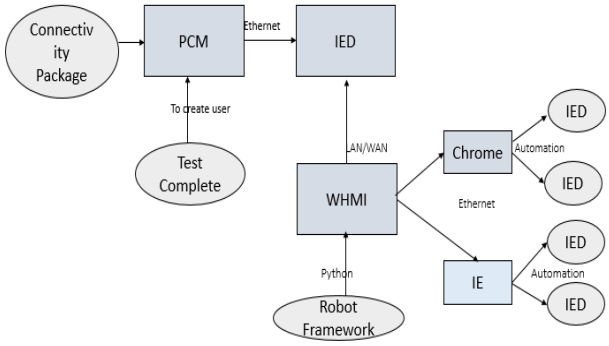

Figure.2. Architecture of the proposed system

A. Web Human –Machine Interface (WHMI)

WHMI is the web application to log in to the IED through the web. Web HMI provides the interface between the user and the IED. In the proposed system, user is directed to the IED through the WHMI using its IP address as its URL. Before permitting access to the IED the user is authenticated. The Figure.3 shows the WHMI page.

B. Features of WHMI

WHMI provides the interface between the user and the IED. Instead of each time going near the IED and accessing the IED we can access it from far also. IEDs have several functionalities they can be monitored and configured using WHMI. Without intermission of PCM, user can activate or change the required setting group. We can also get the information regarding the installed hardware in the IED and the production versions and also we can change the IP address accordingly etc. This page consists of menu items describing the functionalities provided in this application. Initially the manual testing of the WHMI has been performed. The data received from the manual testing is gathered and analysed. Based on that data the automation cases has been designed. Once the test suite for automation is ready this can be put for end to end execution and it is expected to achieve the end to end execution of the test cases. Automation of IED through Web HMI can be done using the Robot Framework tool.

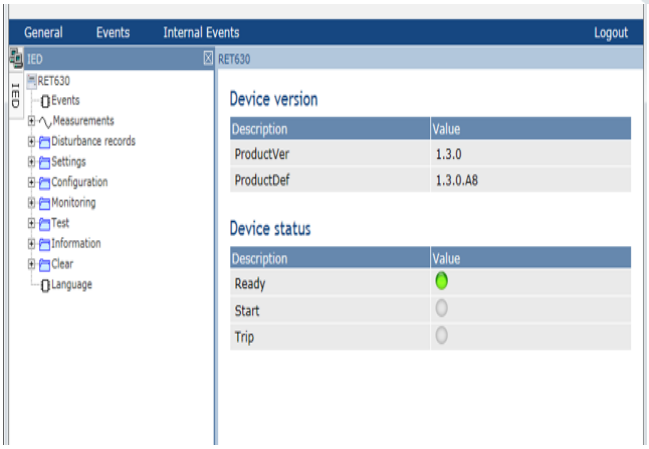

Figure.3. WHMI page

C. Using Robot Framework

Figure.4 shows the primary requirements before we start with the automation. Prerequisites for testing are installing the Robot Framework in the Pycharm community. Then importing of the Robot framework support selenium library and the relative Web drivers for the automation of web application. To execute robot files the Pycharm has to be installed with Robot Framework support plugins. All the libraries are installed using the pip. All the installed libraries should reflect in the project interpreter.

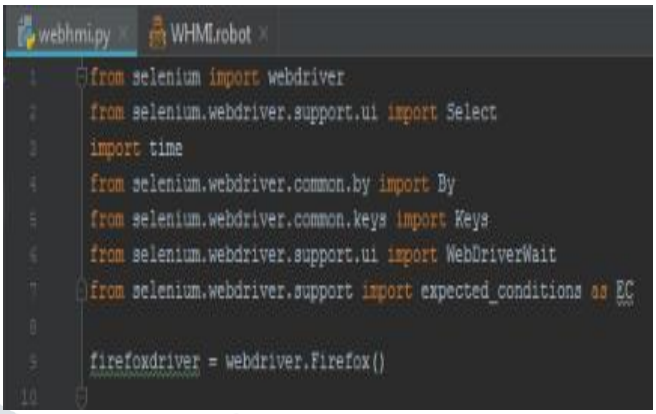

Figure.4 Libraries imported in RF

D. Testing

Once the setup is ready, based on the requirements test scripts are written. When the test suite is ready, IED can be tested through WHMI using different browsers simultaneously and also using a single browser many IED's can be tested. In the proposed system, the manual testing of the IED using Web HMI can be automated using the Robot Framework tool. Initially an IP address is configured to the particular IED. To access the IED the system has to be connected the network to which the IED is connected. For example the test cases be like disturbance handling report, setting group selecting etc Disturbance handling gives the status of the IED when the trip is happened, and also the status of the voltage and current. IED will be configured with different type of settings. Without intermission of PCM user can activate or change the required setting group. User can also select the needed binary input and output modules based on which the functional elements make decisions and performs the action. Once the test data is given, a keyword-driven scripts are written for the automation of the test cases. Later end-to-end performance testing is executed. The results generated is verified with the actual results.

IV. PERFORMANCE ANALYSIS

Table.1 shows the list of test cases performed for the WHMI. The comparison graph has been generated as based on the time consumed by manual testing and automation.

	TEST CASES
Case1	To log in and log out from the IED.
Case2	To select the required setting group.
Case3	To clear the events appearing in the event list.
Case4	Check for the internal events and get the count of the internal events.

Table.1. List of the test case

Figure.5. shows the logs generated for the WHMI test suite. Here, as an example login and logout from the IED using the Web HMI is considered. It takes the maximum of 30 seconds to perform the above case. But if it is

performed manually it will take nearly 90 seconds. Thus the automation of WHMI can be efficient over the manual testing of WHMI.

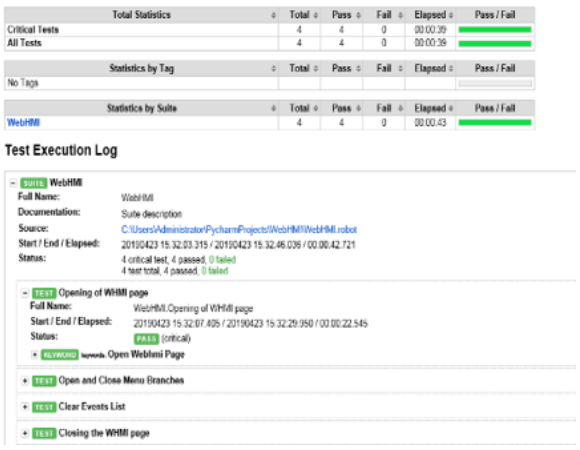

Figure.5. Logs of the WHMI test cases

Figure. 6 shows the performance graph of the WHMI. It is observed from the graph that there is some amount of difference in the time between the manual and automation testing in the each case. When it has to be performed with many test cases there will be large amount of time difference generated. Hence it is a better way to choose automation.

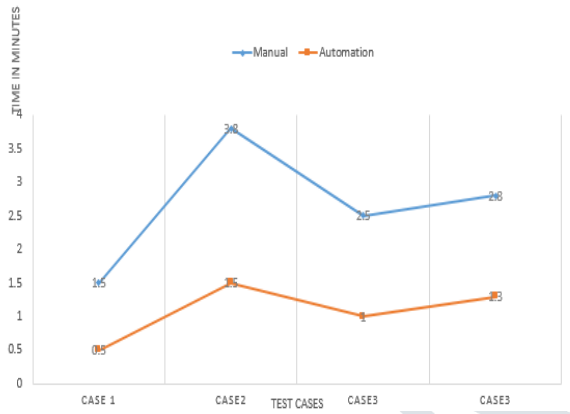

Figure.6. Performance of Manual v/s Automation

Here as we are using keyword-driven test approach the test suite size will be lesser and the script maintenance becomes easy.

V. CONCLUSION

In this paper, we have described a method for verifying the Web application design. This is proved using the web application WHMI. All the intrinsic information generated about the devices can be easily accessed by operator and maintenance system, as WHMI generates alarms. So maintenance of the subsystem becomes easier. WHMI have a login password and hence it cannot be used by the unauthorized users. Using Robot Framework the human operator is not required and the system under test can be completely automated. By implementing proposed methodology we can obtain end to end execution of the test cases using open source platform robot framework. Once the test suite is ready this can also be implemented in various browsers. One IED will take minimum of three hours so if we automate it for once, these can be triggered overnight.

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