The Data Acquisition and Control Unit Design for Demand Side Low-Cost Customized SCADA

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***Abstract*— Supervisory control and data acquisition system (SCADA) holds significant value in power and energy system. But, in case of demand side load management, SCADA seems so expensive. To make the customized SCADA system more efficient and less costly the RTU concept has been proposed. This paper represents a standard data acquisition and control unit (DACU) design for low-cost customized SCADA, which can be usable for demand side load management. C-SCADA will then be divided into two major parts. One will be DACU and the other one will be the processing unit. This DACU promises to be portable and cost efficient with accuracy. With this DACU, electrical mapping and control of mid-level power consumption can be done in a hassle-free way. DACU can be named as $\mathrm{DACU_X}$ in case of multiple deployment. After multiple test sequences, the data acquisition error rate and switching time has also been calibrated.**

Keywords*— Data Acquisition, Control, Modern RTU, SCADA, ASC-DSL, Customized, Portable Unit, Web-Interface, IoT, Universal, Demand Side Load, Power, Communication.

I. Introduction

Supervisory Control and Data Acquisition System (SCADA) has become so expensive to maintain the intelligence for demand side load [1-2]. Numerous techniques have been introduced so far to make the phenomena operative in an optimized way [3-5]. In [6], S. P. Anjana and T. S. Angel, researched on demand side management for residential load and smart micro-grid. S. Paramasivam, L. Thillainathan and their team nearly implemented a cost-effective real-time SCADA for residential need [7]. B. Pillai, V. Mehta and N. Patel also developed SCADA for mini thermal power plant in [8]. But, a universal Customized-SCADA (C-SCADA) design has not been introduced on any of those mentioned researches. Also, the Remote Terminal Unit (RTU) sections of those C-SCADA had been implemented in the traditional way. Recently the revolution of 5G technology and its application is gaining high intensity among researchers' brain. The data acquisition technique has become more versatile now. L. D. Cuayo, J. K. Culla and their team, developed a wireless RTU type unit which has been usually three microcontroller-based system [9]. The team of Cuayo, had given great effort for the research. They had successfully improvised the RTU for wireless connectivity. But basically, it has been a data-transceiver which has been modified by Arduino Yun module. As, the core unit still depended on the expensive supervisory system, the Arduino Yun could have been more useful to make the system less costly. In [10], L. O. Aghenta and M. T. Iqbal, had done an outstanding work by developing an IoT-based SCADA system for PV system monitoring. They have used Arduino Uno as sensor gateway and Raspberry Pi 2 (interfaced with Node-RED) as data acquisition and transfer unit. It has been a good work for data acquisition system. But as the system was only for monitoring, the control part had been absent. So, the system can only monitor without being able to control in this case. In [11], a universal demand side load side C-SCADA model had been proposed and implemented for single phase mid-level load category. That system architecture also showed power saving method, which had been driven by client-preferred algorithm. This model had five units, where XCU was the control unit with built-in data acquisition system. However, to serve as an accurate data acquisition and control unit, a universal Data Acquisition and Control Unit (DACU) should be introduced.

The objective of this work is to demonstrate the use of a universal DACU design for existing low-cost web-based or IoT-based C-SCADA, usable for demand side load management.

II. The DACU Design for Existing ASC-DSL

The core of Advanced Supervisory Control system for Demand Side Load (ASC-DSL) [11] validates the cost effectiveness not only in algorithm-based system run, but also in power saving strategy. On the first illustration of [11], the plan describes the initial C-SCADA design. But to make the DAC unit more universal and portable, it needs a reconstruction like Fig. 1. The DACU of Fig. 1 reflects the updated version of final design.

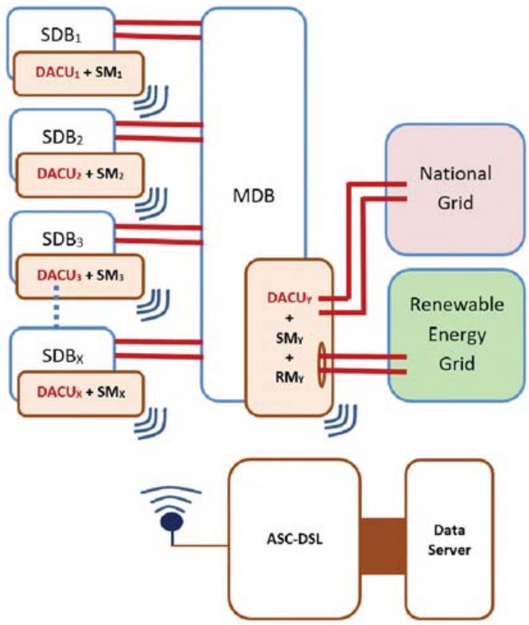

Fig. 1: Data Acquisition and Control Unit (DACU) in C-SCADA system

The system of [11] consists of five major units, which have X Power Saving Unit, X Control Unit, Power Bypass Unit, Advanced Supervisory Control Unit and Data Server. But in Fig. 1, under each Sub Distribution Board (SDB) there is a DACU along with Switching Mechanism (SM). For multiple SDB, the naming has been assigned like $DACU_X$ and SM_X. And for Main Distribution Board (MDB), there is a DACU along with SM and Regulatory Mechanism (RM). To distinguish the unit name, the DACU, SM and RM of MDB has been named as $DACU_Y$, SM_Y, RM_Y. Fig. 2 shows the internal view of $DACU_X$ and SM_X. The $DACU_X$ consists current sensor like ACS712, voltage sensor, microcontroller (Atmega328P) and ESP8266 V2. The necessary collected power data (collected by the sensor, from the power line) are being processed by microcontroller. Microcontroller transfers the processed data to ESP8266. Then, ESP8266 transfers the data wirelessly to the corresponding IP address in preferred user interface or Intranet-based ASC-DSL system. SM_X is the secondary part which can be adjustable due to system necessities. This part has the switching mechanism that is interfaced with the microcontroller pin of $DACU_X$.

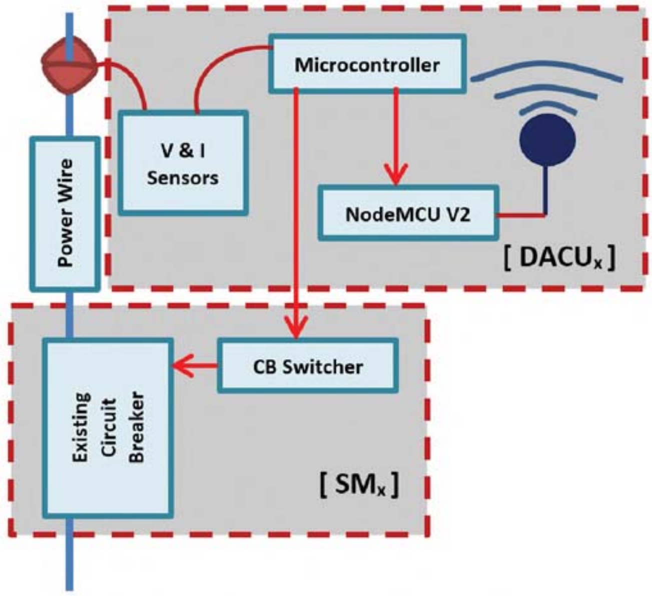

Fig. 2: $DACU_X$ design in each SDB for C-SCADA

In Fig. 3, it can be seen that $DACU_Y$ is as same as $DACU_X$ design. This design validates that, DACU system is universal and portable unit for the C-SCADA system. As, the mid-level demand side power consumption has no complex power system analysis, the unit can be easily deployable. But in MDB, along with DACU and SM, the Regulatory Mechanism (RM) should be introduced, the power electronic triggers should be connected to the microcontroller pins. This RM will regulate the power inlet from National Grid (NG) or Renewable energy Grid (RG) into the MDB by the instruction from microcontroller. This instruction will be sent to the ESP8266 and microcontroller to feed the bus bar. From Fig 2. and Fig. 3, it can be seen that, $DACU_X$ and $DACU_Y$ is same in circuit parameters. So, it has been validated that the DACU will be universal and portable. As the C-SCADA is customizable, so the SM and RM technology will vary upon the design of engineers and client's requirement. This SM and RM design can be magnetic, power electronic, electrical, which may also vary due to system requirements.

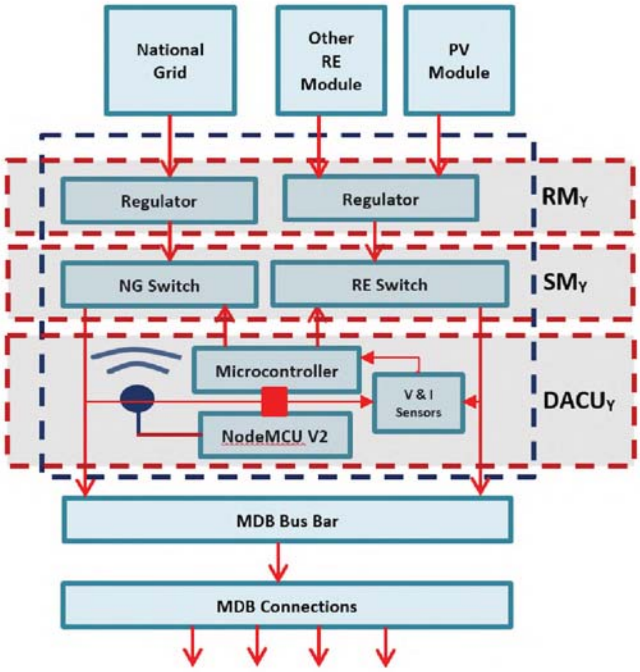

Fig. 3: $DACU_y$ design in MDB for C-SCADA

III. Prototyping the Design of DACU

As DACU holds significance to be universal according to the design analysis, implementation of DACU for either on the SDB side or on the MDB side remains same. Initially the DACU has been deployed for three SDBs of two floors. Every SDB consists of the circuit parameters shown as Fig. 2. The collected information of each SDB have been transferred to the system parameters.

A. DACU for Two Floors (with Three SDBs Each):

The two light brown colored board in Fig. 4, represents two floors. And it can be seen that each board consists of two Circuit Breaker (CB). Each CB has been considered as one SDB. Under each CB, the sample load section has been connected. The experiment has also been tested on the same number of CBs of university building. After the successful operation, it has been represented in these two boards for proper visualization.

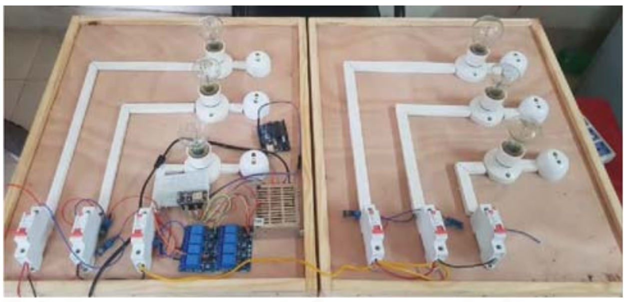

Fig. 4: Prototype for two floors with three SDBs each (six DACUs), one DACU has been deployed in the figure.

B. Provisional UI of DACU Screen in Web-Based Platform:

The provisional User Interface (UI) has been developed to validate the data acquisition and control criteria of DACU. Usually, this experimental UI will be replaced by the C-

SCADA UI. The DACUs can be re-programmed for the data transfer and control algorithm as requirement.

All the SDB's current, voltage and power information have been centralized in one screen like Fig. 5. It has been designed in such a way that the data can be visualized in one sight. To ensure the controlling part, only one switch (on/off) has been assigned in this test screen.

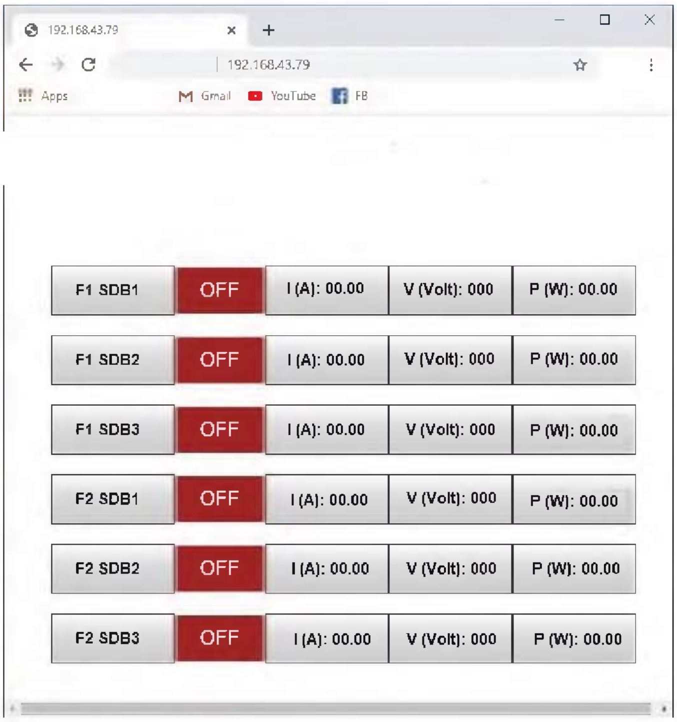

Fig. 5: Provisional UI for all DACUs in one screen

For each SDB, the individual DACU screen has been tested for individual data analysis and control feature. In Fig. 6, the snap of individual DACU screen has been shown. Here, current, voltage and power data have been focused. For control feature, one (on/off) switch and one automated shutdown switch have been generated for over 5 kWh rated power consumption.

Fig. 6: Provisional UI for each DACU

IV. Result and Analysis

The experiment has been done under the concept of modern C-SCADA plans. The data that have been represented are regional values and consumption on specific season.

A. Data Acquisition Accuracy:

The experiment has been carried out for single phase load only. Various load scenario has been tested here. SDB to SDB the power consumption has been varied for the analysis. 50 Watt to 150 Watt have been tested. Resistive (R), Resistive-Inductive (RL) and Resistive-Inductive-Capacitive (RLC) type loads have also been tested. The table that has been placed below, shows the best-fit data of the research. From the table, the average accuracy of this data acquisition system has been recorded as 98.57%. However, this accuracy can be improved if advanced sensor can be introduced. Also, the error can be optimized by scrutinizing the error curve points. After identifying the curve equation, it can be adjusted from sensor data-accumulating and error-optimizing equation.

Table I. Instantenous Data Analysis from UI

Test Area	Necessary Acquired Data			Comparison		
	Voltage (V)	*Current (A)*	*Power (Watt)*	*Rated Power (Watt)*	*Accuracy (%)*	
					Per Test	Per DACU
SDB 1 (Floor 1)	221	0.113	25.19	25	99.24	98.20
		0.109	24.09		96.36	
		0.112	24.75		99.00	
SDB 2 (Floor 1)	220	0.181	39.85	40	99.62	99.14
		0.178	39.16		97.90	
		0.182	40.04		99.90	
SDB 3 (Floor 1)	220	0.179	39.38	40	98.45	98.38
		0.183	40.26		99.35	
		0.177	38.94		97.35	
SDB 1 (Floor 2)	218	0.270	58.86	60	98.10	97.73
		0.266	57.98		96.63	
		0.271	59.08		98.47	
SDB 2 (Floor 2)	220	0.269	59.18	60	98.63	98.51
		0.272	59.84		99.73	
		0.265	58.30		97.17	
SDB 3 (Floor 2)	219	0.455	99.65	100	99.65	99.44
		0.451	98.77		98.77	
		0.457	100.1		99.90	

B. Control Response Analysis:

The control response seems faster like real-time. There also have been some automated instructions that has been performed after certain changes in load. In manual switching criteria, it took around 151 ms on average to operate. Fig. 7 demonstrates twenty instantaneous response-data analysis.

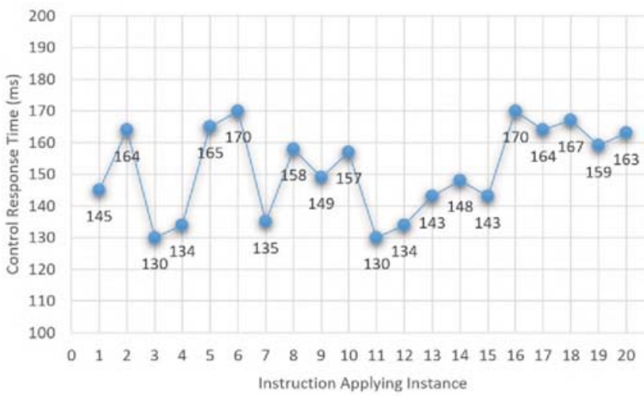

Fig. 7: Control response time for manual instantaneous instructions

In decision-based automated switching, it took around 242 ms (in average) to take over the emergency instructions and around 350 ms (in average) to take over usual instructions. Fig. 8 represents the response analysis of this case.

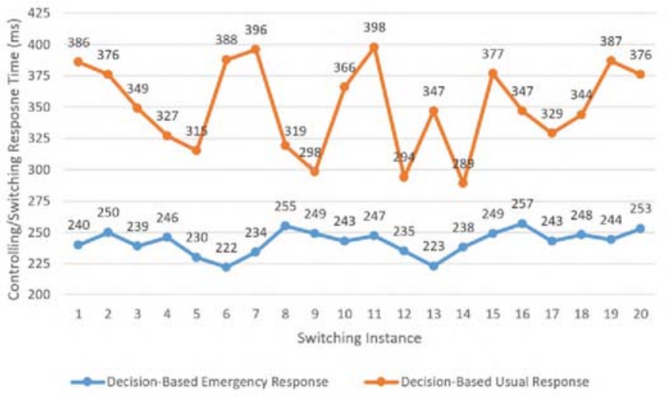

Fig. 8: The response analysis of decision-based switching of DACU

With this DACU control, power consumption can also be controlled with the assistance of Power Saving Unit (PSU) of [11]. The optimization algorithm of [11] has been overridden for this DACU design to test several phenomena. Fig. 9 shows the power consumption time optimization analysis, controlled by DACU in a web-based C-SCADA. The vertical axis is in minutes. The blue line represents the power consumption time in a class room from 8 am to 5 pm. And the orange line represents the optimized consumption that has been controlled by DACU.

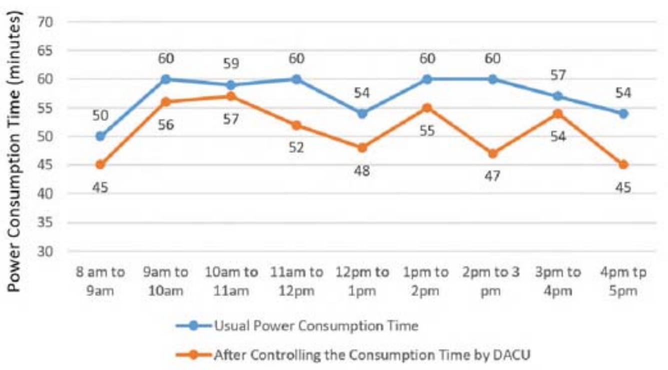

Fig. 9: Power consumption time optimization analysis by DACU

V. Conclusion

Customized SCADA (C-SCADA) is the recent solution of demand side load management. Due to this C-SCADA, the data acquisition and control unit has to be less costly and efficient. In this research, the demonstrated DACU design has been efficient with 98.57% accuracy in data accumulation task. From the result analysis section, the control response has also been validated as close as the real-time response. The DACU design has been universal and portable. That means, in any C-SCADA system, this type of DACU design can be implemented with any user modified code to run the C-SCADA decisions efficiently. This low-cost (in comparison to traditional remote terminal units) unit has been validated its ability for single phase mid-level power consumption criteria. The control setup has been tested for both manual and automated state. For the experiments of automated decision criteria, the DACU units have been pre-assigned with few control instructions so that the capability can be tested. In future, this decision will be fed to the DACU's microcontroller by the core processing unit like the Advanced Supervisory Control (ASC) unit of [11]. This unit can be easily implementable for 3 to 4 MWh side easily using 30 A to 60 A tolerable current sensor and accurate voltage sensor. In case of the HVAC and HVDC criteria of demand side, the analysis will be done in future. Apart from those, DACU can be useful to assist power saving strategy in any C-SCADA system. With low-cost design, portability and efficient data accumulation structure, this DACU design can be the inspiration to let the future generation build customized SCADA with power saving and intelligent algorithms.

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