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# Distributed Transformer's Health Monitoring Based on Internet of Thing and Publish/subscribe Messaging Paradigm

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**Abstracts:** Since, "prevention is better than cure", transformers monitoring system is essential to optimally utilize and hence increase life time of these distributed equipments in the power grid. In this study, a new approach is applied to do that job by integrating three technologies: General packet radio services (GSM/GPRS), internet of things and publish/subscribe messaging paradigm. Practically, researcher found that publish/subscribe messaging model fits several requirements of IoT as it allows data to be sent based on interests rather than agent addresses and releases the topology of the network. In addition, GPRS services increased mobility and reliability of the system. However, the deigned system implemented three parts: Transformer Agent (TA) which instills at transformer site to collect operationkey parameters, dweetplatform as broker server which realizes connection between publisher and subscriber and finally, graphical user which interfaces program to display information coming from remote TAs. While, the designed system is installed and tested at the laboratory environment, it gave freedom to select different sensors package according to actual needing. The system gave good results as early warning and it has high interoperability and scalability with lowest cost for deploying.

**Key words:** Publish/subscribe paradigm, dweet, IoT, distribution transformers monitoring, arduino, SM5100B-D, transformer agent

## INTRODUCTION

"Internet of Things (IoT)" refers to the interconnection of different kinds of resource-constrained devices, in order to build various types of monitoring and control applications. In 1999, Ashton (2009) proposed the ground back for that field. The idea was simple and powerful. If all objects in physical world (called "things") are equipped with unique identifier and connected to internet then these things could communicate with each other's and can be managed by computers or servers. With the development of electronic and IT technology, the range of IoT applications is extended. Utility meter, health monitoring, agricultural automation and tracking system are some examples of that applications.

Distribution Transformers (DT) is one of the most important and vital part in the power grid. In fact, both of quality of supplied electricity and grid stability depend on these equipment in the first degree (Mohammedi *et al*. 2013). Therefore, DT's health monitoring should help to prevent critical and unexpected failures at the same time increasing life span (Wu *et al*., 2011). Authors in earlier studies, applied several techniques to perform this task such as WSN, GSM and recently internet of things (IoT) based TCP/IP protocol (Tao *et al*., 2012; Zou, 2013).

According to Shang *et al*. (2014, 2016) TCP/IP protocol improves hardware and software interoperability and covers large-scale of IoT devices deployment. However, its implementation faced significant issues such as complex network configuration, IP addressing middleware and security mechanisms in addition to consuming IoT devices simple resources. Therefore, usability and innovation in this field widely affected.

In this study, we proposed publish/subscribe messaging paradigm as a solution to overcome all the above drawbacks. This approach is one form of data-centric communication and it is widely used in distributed computing and enterprise networks. It characterizes with loose time coupling, asynchronous, multi-communication between transmitter and receivers and hides the topology of the network. Basically, Publish/Subscribe model consists of three main parts called Publisher, Subscriber and broker. Publishers publish events while subscribers subscribe events. The entity which ensures communication between them is the broker (Li *et al*., 2015).

**Literature review:** Mao (2010) proposed remote monitoring system for power distribution transformers. The design adopted GPRS service to overcome rural hard environment and reduce cost. The system implemented two parts namely: monitoring terminal and monitoring center stations. The researcher success to reduce data collection cost but, unfortunately, he failed to build simple and cheap monitoring center stations on the other side.

Mohamadi and Akbariin (2012) provided a new method based on SMS serviceand web server with data base to monitor remote transformers in power network. The design depended on pre-design software called (DTMAS). The system gave good analysis to each connected units but, it has high operation costsince it depended on SMS services.

Mohammedi *et al*. (2013) developed a system for distribution transformersmonitoring systemin substations based on GPRS and ADSL. The designed system collects several parameters and sent them to control center depended on special IP address. The system used traditional web browser to interface remote units. It is not clear how they used ADSL system, transformer's parameters collected and server site process. Authorsfocus in this research at cost reduction put unfortunately, they fall in the complexity of TCP/IP networking.

Ku *et al*. (2014) developed an intelligent transformer management system. The design consist of three parts namely: TTU, PLC model and automated mapping system. Also, the system used hybrid communication infrastructure (NPLC and then fiber optics) to retrieve the operation data and report the abnormal operation status of remote transformers. In fact, while the designed system has high degree of complexity and costly, our work reduces these characteristics clearly.

The main contribution of our research in this field was came from applying publish/subscribe messaging model to interface remote transformer. This technique support the Transformer Agent (AT) to work under plug and play principle and it released the dependence upon IP address to access remote agent. So, we reduced network mapping complexity at the same time we maintain good values of reliability, scalability and interoperability.

Also, the design gives an opportunity to customize both of sensors board and interfacing program according to actual needing. Where cloud-based virtualization web page can be build using freeboard services instead of LabVIEW program in main control center.

## MATERIALS AND METHODS

**Proposed system structure:** The designed system consists of three main parts namely: Transformer Agent (TA), brokerserver and predesigned LabVIEW GUI program located in Main Control Center (MCC) as shown in Fig 1. Each (TA) deploys near to one transformer in order to acquire vital parameters from that transformer. The total number of these agent in the grid and the types

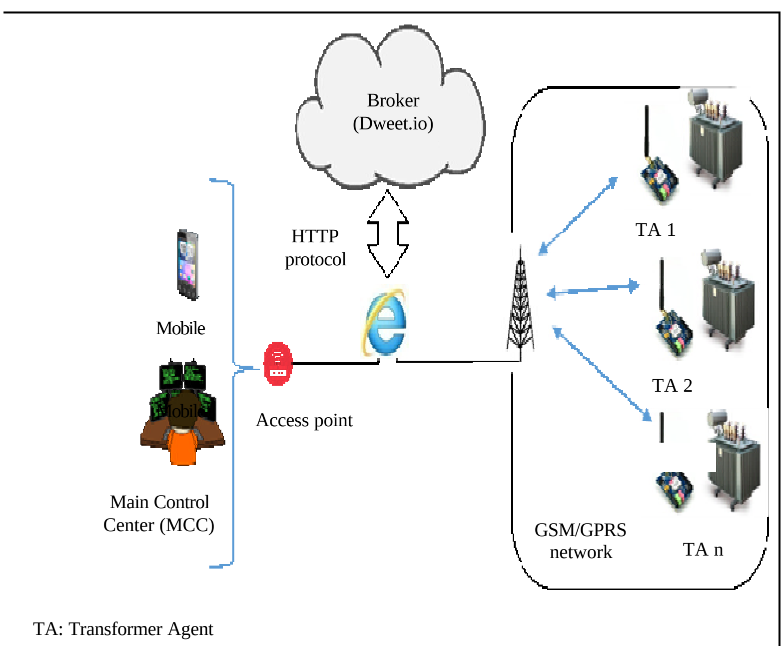


Fig. 1: Proposed system structure

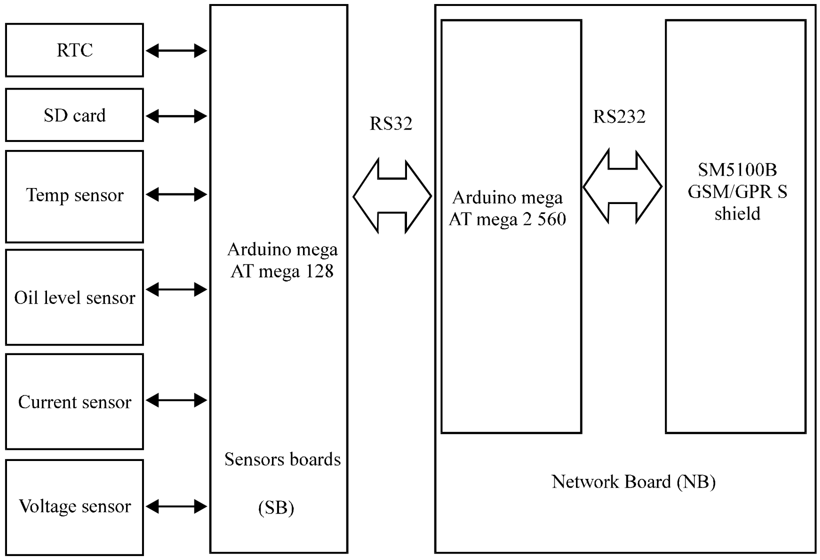


Fig. 2: Transformer agent structure

of sensors in each agent is left to grid operator to decide according to actual needing. This agent dependsupon GSM/GPRS service to access internet and then communicate with broker.

Related to broker, the designed system depends up on (www.dweet.io) services. It is simple and secure topic-based pub/sub platform. Dweet uses web-based RESTful API technique to make IoT'sdevicesaccessible remotely. Also, it supports Machine to Machine (M2M) and visualization applications.

All collected information directed to Main Central Center (MCC) for monitoring and controlling purposes and this is the third part of our design. In this center, a special program is designed using LabVIEW software in order to display all collected information and notify operator in charge if there is any remote fault.

**Transformer Agent (TA):** The designed agent collects physical parameters related to transformer operation like output phase current and voltage, oil level and oil temperature. In this study, designer can customize this agent by selecting sensors according to actual needing. However, the agent consists of two main boards: Sensor Board (SB) and Network Board (NB) as shown in Fig. 2. In SB, Arduino microcontroller is used as a processor.It attached to SD card and real time clock shields. SD card used to store Max. current values consumed by load meanwhile real time clock used to provide time stamp. Practically, SB is responsible for collecting and preparing transformer information and then answer any requests coming from remote MCC.

On the other hand, network board consists of arduino mega microcontroller and SM5100B GSM/GPRS shield. SM5100B chip depends on pre-paid SIM card and AT command to connect network. Basically, this chip is a compact quad-band GSM/GPRS module works at 9600 bps with Quad-band cellular duck antenna, Moreover, it supports serval frequency bands such as EGSM900, GSM850, DCS1800 and PCS1900.While operational voltage is between 3.3 V and 4.2 V (Lee *et al*., 2014). In fact, NB has three main job namely:

- Store the unique identifier name or number related transformer agent (TNN)
- Represented bridge between SB and broker server. It uses serial port to keep contact with SB
- Access internet via GPRS service and establish TCP/IP connection with dweet's server in order to publish data or subscribe things as it is illustrated in Fig. 3

**Broker server:** As it is mentioned earlier, the designed system depend on dweet website to connect all distributed TAs with Main Control Center (MCC). Dweet is a topic-based Pub/Sub messaging platform designed to provide several services to IoT devices such as publishing data, subscribing, alerting and storage. All these services characterized with high reliability, high performance, secure communication channel and low cost. Client mustuse REST over HTTP in order to deal with dweet. If the designed TA wishes to publish data under specific topic (thing name), it uses HTTP POST method with topic name and data. On the otherhand, if the agent interests subscribe to specific topic (thing name), it

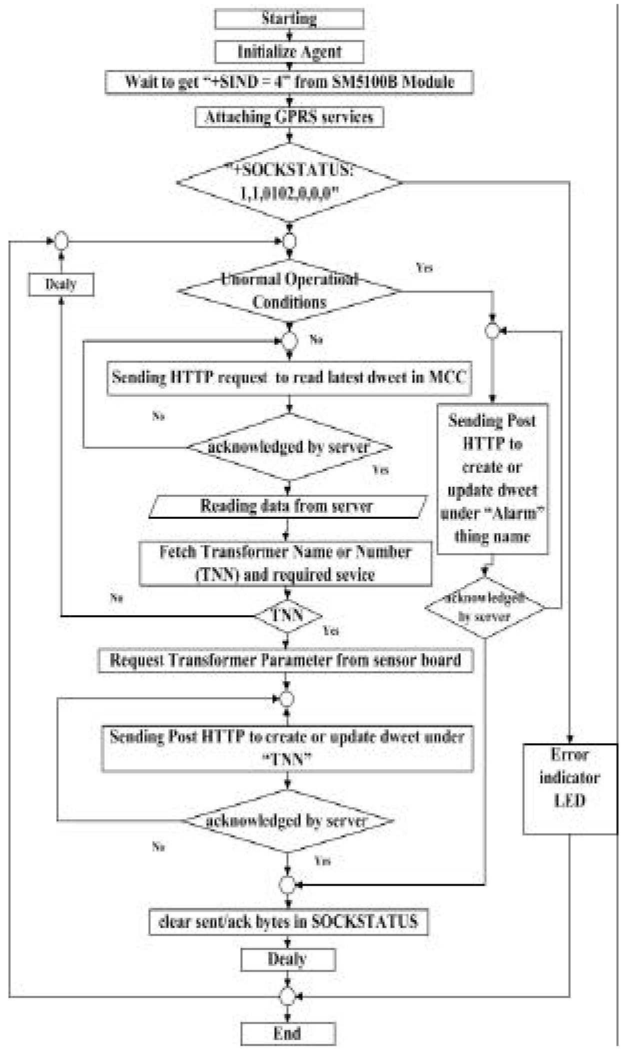


Fig. 3: TA program flow chart

uses HTTP GET or LISTENmethods with the topic name. In both above publishing or subscribing process, Dweet server responses with a message implement operation status, thing name, time stamp and uploadeddata. By this strategy, agents do not require any knowledge about network topology or structure at the same time each agent can deliver data to interest in them without resorting to broadcast. Figure 4 explains publishing and subscribing messaging paradigm via., dweetserver.

**Graphical user interface:** Lab view program is designed in such a way that a person in charge can monitor and control each distributed transformer remotely. As shown in Fig. 5, GUI divided into two tabs. The first tab contained fault monitoring. This table helps the person in charge to monitor all the distributed transformer status in the grid. It displayed information about fault which it sent earlier from TA. In the second tab, specific remote transformer is interfaced. The person in charge needs to submit Transformed Name or Number (TNN) with wanted services and press request button. After little time delay, transformer information is displayed. In this study, the designed prototype system monitored phase output current and voltage, Max. load current with respect to corresponding time stamp and oil temperature and level. In addition to predesigned GUI program, cloud-based visualization website implemented in anysmart phone or any computer using.

**System operation:** Before describing system operation, it is important to understand dweet map. As shown in Fig. 6 each TA deals with three topics (thing name) namely: TNN, Alarm and MCC. "TNN" is a thing name used to upload transformer data which iscollected by TA.

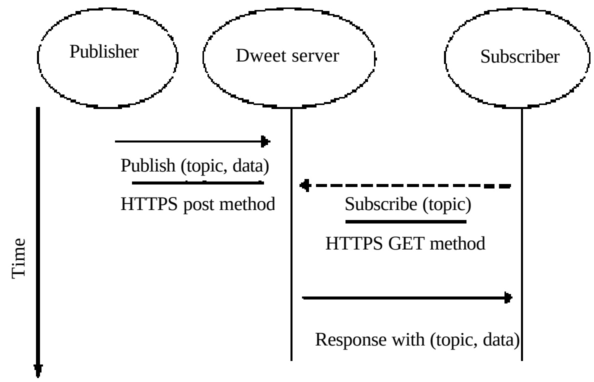


Fig. 4: Communication to Dweet using restful API web services

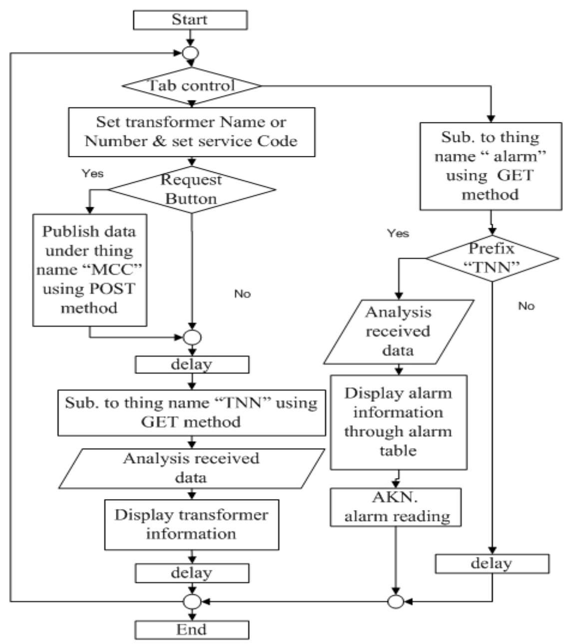


Fig. 5: GUI flow chart

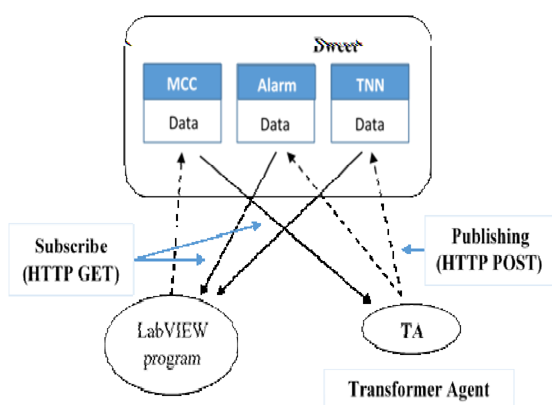


Fig. 6: Signal agent communication model with the main control center via dweet server as broker

Therefore, each transformer is represented by unique thing name in dweet. While, "Alarm" is a thing name used to upload error code generated earlier by TA. In fact, "Alarm" is a global topic in the system and it can be used by all TAs in the grid. Finally, "MCC" is a global thing name used to upload command from the Main Control Center (MCC) to this end, the operation of designed system is summarized in the following points. Starting from the main control center to Transformer Agent node (TA) and then comeback to the main control center.

In MCC, the person in charge uses LabVIEW program to bring remote transformer data. Transformer Name or Number (TNN) must be submitted to gather with required service. Then "Request" button must be pressed. The designed program starts to trace request operation and give indication at "Request Status LEDs".

After press the request button, LabVIEW program will publish information under thing name MCC. This information contained transformer name or number, services required from TA and termination character. Since, MCC is a global topic in the system, all TA subscribes to it and receives any new update. Practically, only TA with matching TNN responses to that command.

At this point, TA realized that the coming command is directed to it. Immediately, network board passes command to sensing board via., serial connection. According to required service, sensor board starts to collect data, make mathematical process, add time stamp and then deliver results values to network board in order to send them back to main controller center again.

After serial transition is completed, network board immediately publishes all received information under thing name "TNN". Dweet server will create thing with name TNN if the thing is not already exist.

On the other hand and after the first point in this summery is completed, LabVIEW program started to read last dweet on thing name TNN using HTTP GET method periodically. As soon as point 4 of this summary executed, contained data is directed to LabVIEW programby this mechanism, LabVIEW program changes from publisher to subscriber.

Finally, if TA detects up normal condition related to transformer operation, it immediately publishes corresponding error code under the global thing name "Alarm". With the same pervious mechanism, LabVIEW program obtains this code and shows it at error table in GUI.

## RESULTS AND DISCUSSION

The designed system is tested in lab. environment. Voltage, current, oil level sensors are simulated by using potentiometer in order to obtain different analog values easily. However, the experiment consists of one hardware and five simulated (TAs).The hardware one isattached to temperature sensor, SD card shield and RTC shield as shown in Fig. 7. Transformer Name or Number (TNN) of these agentsare set to "1234, 1233, 1222, 1221, 1134, 1321 and 1232". In addition, one service enabled here and it assigned to number "1011".

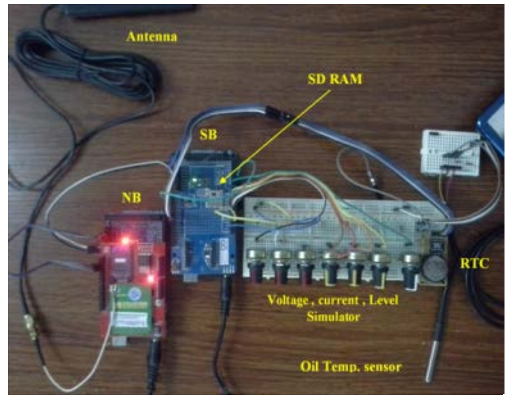


Fig. 7: Designed TA

Figure 8a illustrats LabVIEW program in the main control center. In part a, different artificial alarms are displayed. These alarms are made by simulating abnormal operation conditions inside the remote TA. On the other hand in part -b, operator in charge submits key information (TNN and service number) to obtain remote information from specific transformer or faulty one. Basically, both of alarm code and transformerreal-time information brought to the main control center using RESTful services from dweetserver as shown in Fig 9. Moreover, customize and mobile GUI is developed based on other services introduced by IoT-clouds in order to increase system reliability and mobility as shown in Fig. 10. Practically, topic-based pub/sub mechanizes (like dweet.io) enabled all IoT devices to talk the same language in such a way that devices from different venders or different protocols can communicate. Therefore, the proposed system increasesinteroperability function. Meanwhile, eachTA was uniquely identify by its name or decimal number instead of IP address. So, the hard job of addressing schemes has been eliminated here and atthe same time scalability property has been increased while effort is reduced clearly.

Finally, according to the results obtained, the designed Pub/Sub system presented in this study worked with efficiency, low cost and low network latency.

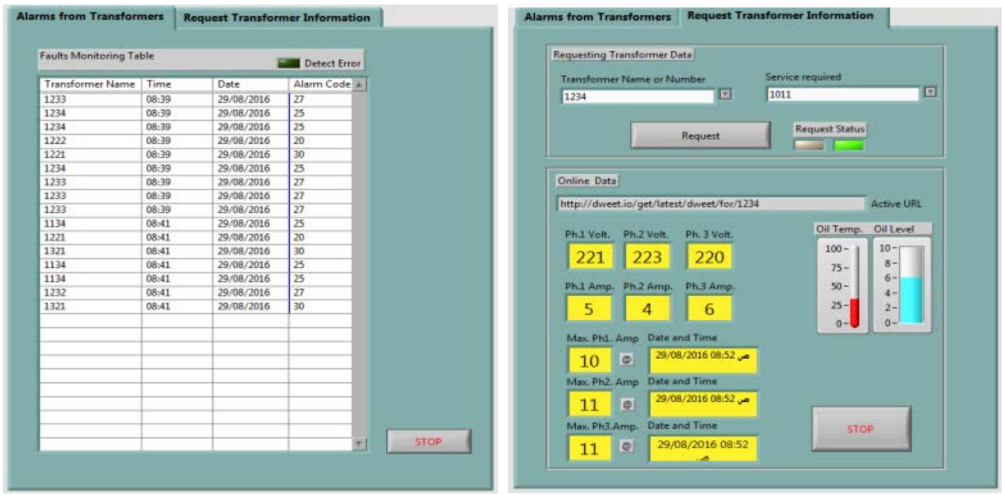


Fig. 8: a) Main control center GUI with different alarm codes; b) Obtained remote transformer data

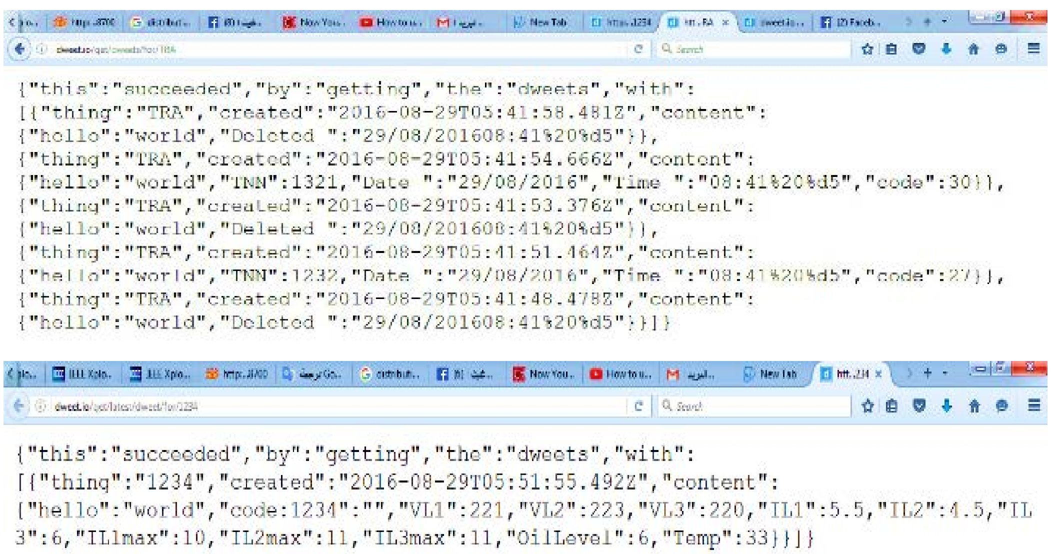


Fig. 9: Uploaded data to dweet server

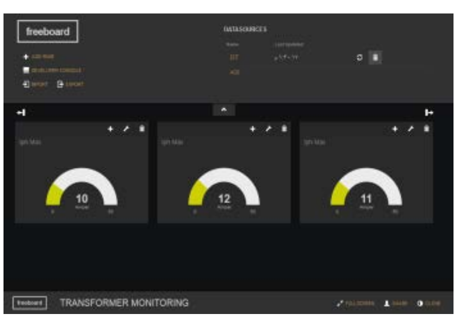


Fig. 10: Customized GUI using freeboard to display Max. current delivered by transformer

## CONCLUSION

In this study, a new method is described in order to automate all transformers in distribution grid. Remote condition monitoring of these unitsare still important to reduce maintenance cost, manage consumer load efficiently and hence increase transformer life time.As it is seen in the previous sections, modern technologies like Internet of Things, Publish/Subscribe messaging paradigm and General Packet Radio Services (GPRS) are integrated in this design. However, mixing of these fields in one system improved reliability, scalability and interoperability properties. Moreover, pub/sub messaging paradigm eliminated addressing effort by using unique identifier (name or number) instead of IP to communicate with any unite. This step takes us forward in the direction of applying plug and play technique and supports smart grid idea. The proposed system can be improvised by using MQTT protocol instead of RESTful. Also another functions can be added to the system such as monitoring circuit breaker or connected GUI to data base structure.

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