A Development of Flexible Real-time Database Platform of Microgrid Energy Management System for Generation Applications

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Abstract

Recently, there have been more needs of the integrated efficient and systematic microgrid energy management for increasing distributed energy resources (DER). The configuration of microgrid is generally so variant that it is difficult to be standardized. For the fast and complete integration of software applications over each microgrid, a flexible real-time database (RTDB) platform for microgrid energy management system (EMS) is proposed in this paper. On the proposed platform, the existing applications can be easily modified or the new applications can be comfortably developed due to easy building of complex database for applications. Furthermore, the architecture of multi-hierarchical RTDB and the virtual region of RTDB, so called application common model (ACM) are proposed for multi microgrid. Finally, microgrid EMS is developed based on ACM with integrating IEC 61850 gateway, common information model (CIM) based web interface, and generation applications package. The field tests in two demonstration fields are performed and the results show that the proposed RTDB platform and the generation applications package are effective in the real-time environment.

Keywords: Microgrid, Energy management system (EMS), Distributed energy resources (DER), real-time database (RTDB), Application common model (ACM), Common information model (CIM), IEC 61850 gateway

Introduction

Recently, much more generation facilities are installed in distribution power system of the medium voltage level or even of the low voltage level, so that the generation facilities are located closer to the area having high electrical demands and can constitute a small scale of power grid in conjunction with its multiple groups of loads. There have been more needs for the integrated efficient and systematic microgrid energy management [1]. Microgrid can be operated in parallel with the main grid or isolated independently, that is, the former is called on-grid mode, and the latter is called off-grid mode or island mode [2]. In respect of energy management, the main objective of on-grid mode is to minimize the operational costs with the tariffs which is imposed on the customer or the owner of microgrid at point of common coupling (PCC), and the main aim of off-grid mode is to maintain the frequency or voltage within a certain limited value while keeping the balance between supply and demand.

Several studies have examined energy management of microgrid [3]-[7]. There are two approaches to energy management of microgrid; the centralized energy management and the decentralized energy management [3]-[6]. The decentralized energy management is mainly based on the multi-agent technology [7]. Olivares et al. [4] deal with the generation scheduling by decomposing into unit commitment and optimal power flow. Valencia et al. [5] propose the scenario based EMS where scenario is made by fuzzy interval model. In Palma-Behnke et al. [6], energy management system (EMS) based on the rolling horizon strategy is proposed for generation scheduling. Generally, the centralized energy management has three levels of control hierarchy; the primary control, the secondary control, and the tertiary control, but three levels of control’s operation is a little different in each research.

Three levels of control in this paper is defined as follows. The primary control means the local control where Distributed energy resources (DER) are controlled autonomously in milliseconds by control target value. The secondary control means the management system level of frequency regulation or the voltage regulation in seconds by using droop characteristics for the parallel operation of DER. The tertiary control means the economic dispatch of DER in minutes including a couple of days ahead or twenty-four hours ahead generation scheduling. Electrical or heat load forecast as well as renewables forecast have to be performed in advance of the generation scheduling. All of these applications are so called generation applications package as Figure 1, and it is implemented on the proposed real-time database (RTDB) platform which will be described in detail in Section 2. The configuration of microgrid is generally so variant that it is difficult to be standardized. To cope with this problem, a flexible RTDB platform for microgrid EMS for the fast and complete integration of software applications over each microgrid is proposed in this paper. Then, the
architecture of multi-hierarchical RTDB and the virtual region of RTDB, so called application common model (ACM) are proposed for multi microgrid.

The international standard IEC 61850 is generally applied to the power system substation automation in medium or low voltage level [8]. However, the legacy communication protocol such as RS-485 or Modbus protocol, etc. is still widely used for almost of DER. For easy integration of the communication system of DER in a medium or low voltage level, IEC 61850 becomes more important as a communication standard for microgrid. In addition, IEC 61970-301, called common information model (CIM) is applied to the recent EMS for data exchange between EMS itself and the other EMS or for compatibility of its unique applications [9]. IEC 61850 gateway for the integration of different protocols of DER and the web interface system with IEC 61970 compatible offline database are developed and described briefly in this paper.

Finally, microgrid EMS is developed based on ACM with integrating IEC 61850 gateway, CIM based web interface, and generation applications package, and then the main two field test are performed.

**Microgrid EMS**

**Microgrid EMS Architecture**

Figure 1 shows the developed microgrid EMS architecture. The measured data from IEC 61850 gateway is firstly processed in the data acquisition and control package, and then in the real-time data processing package. For the efficient and reliable process in generation applications package, the measured and unmeasured data of DER and another concerned meaningful data have to be stored in IEC 61970 compatible offline database. IEC 61970 deals with the application program interfaces for EMS, or CIM, defined in unified modeling language (UML) notation and it consists of classes and attributes for these classes, as well as the relationships among them [9], [10]. IEC 61970-501 and 61970-452 standards define an XML format for network model exchanges using RDF [10], [11]. CIM can be implemented using generic relational database management system (RDBMS) such as Oracle, MySQL, SQLite, etc.

**RTDB and Offline Database**

The basic structure of RTDB structure is proposed in this paper to construct easily the vertical hierarchy or direct relationship with class, attribute, method, and item as shown in Figure 2a. Class represents the object, or instantiation of class, and attributes contains data type and array size of array. Method is the set of preserved functions of the corresponding attributes and item is the argument of the corresponding method. Complex relationships can be defined in schema file by using the proposed basic structures. The text-based schema file is parsed, and then the concrete objects with complex relationship are built in shared-memory for exchange of data among application processes of application packages as shown in Figure 2b, where the special virtual region called ACM in RTDB is created and it will be used by the specific applications for generation applications package.

In summary, classes with some attributes containing the preserved useful methods can be easily expressed and
editable with text-based schema file, from which ACM is automatically updated. The methodology of building the data structure for applications package is flexible and it helps to extend the practical application field. There are essential reserved attributes, or “UpLink” and “Downlink”. The attribute “UpLink” is used to express the multiple to one relationship, or child to parent, and the attribute “Downlink” is used to express the one to multiple relationship, or parent to child and its main aim is the fast search. The linked list information of “Downlink” is stored in the corresponding attribute, or “UpLink” at the system initialization stage, which is defined in schema file by the reserved keyword “AddChild”. Figure 3 illustrates the example of creation of ACM where Level1 LVL_1 in the 2nd level has generator Gen1 in the lowest level and LVL2_1 in the 3rd level. 2 in Class in “UpLink” attribute of Gen1 indicates class <Level1> with ClassID 2 in schema and 1 in OBJ in “UpLink” attribute of Gen1 indicates LVL2_1 with object ID 1 of class <Level1>. 1 in array[1] in “Downlink” attribute of LVL1_1 indicates LVL2_1 with object ID 1 of class <Level2>. 2 in Sibling in “UpLink” of LVL2_1 indicates next object id, or LVL2_2 in linked list. Also, 100 in array[2] in “Downlink” attribute of LVL1_1 indicates Gen1 with object ID 100 of class <Generator>. Apart from direct relationship, indirect link relationship as shown in Figure 4a is required to express more additional relationship. The new attribute “indirect_link” is designed and the linked list information of “indirect_link” is stored in the corresponding attribute in the same way as “Downlink” at the system initialization stage, which is defined in schema file by the reserved keyword “IndirectSource”. Figure 4b illustrates the example of creation of ACM where Level1 LVL2_1 in the 1st level has generator Gen1 in the 2nd level and LVL22_1 in the 1st level. It can be known that there must be an indirect relationship between Generator class and Group class in IndirectSource <Group> from schema. The concrete data is instantiated at system initialization stage, which is the same way as direct relationship.

Figure 3: Creation and instantiation of direct link relationship in RTDB from schema

Figure 4: Indirect link relationship: (a) Conceptual diagram in RTDB; (b) Creation of indirect link relationship in RTDB from schema

The input data in the general applications package, e.g. real-time data processing package or data acquisition & communication package in Figure 1 is generally created by administrator or operator in the field using text-formatted sheet for convenience, and the unique identification is provided to the individual input data at that time, so that the final data must not be stored in well-organized and contiguously allocated form. However, the contiguously allocated data is most appropriate for generation applications and network analysis applications, so that ACM in the virtual region as shown in green-shaded region in Figure 5 is proposed in this paper for the purpose of easy access and fast calculation of applications package. Furthermore, indices of objects in RTDB of parent center can be grouped and distributed to RTDB of the child centers, which is helpful of constructing multi microgrid EMS. For example, applications in local center 1 can see only its entries with physical object ID, 1 and 999 which have virtual object ID, 1 and 2 and can be accessed through ACM in the virtual region. Applications in local center 2 can see only its entries with physical object ID, 3 and 4 which have virtual object ID, 1 and 2 and can be accessed through ACM in the virtual region. It can be known that that how to process the data in...
applications of local center 1 is perfectly the same that in applications how to process the data of local center 2. Finally, the central center has all of entries with physical object ID, 1, 3, 4, and 999, and their virtual object ID are 1, 2, 3, and 4, respectively. It should be noted that the physical indices are unique in all of central center, local center 1, and local center 2, and that the virtual objects in ACM have contiguous indices.

Both of offline database and real-time database are used in the developed EMS. IEC 61970 has many packages for EMS, e.g., generation, wires, topology, load model, core, etc. and it is applied to construct offline database. For example, the developed logical database can be shown in Figure 6a, which illustrates ER diagram over the partial part of generation package of IEC 61970-301 and will be used for the data exchange between other EMS. Figure 6b shows the proposed data structure of ACM for generation applications package and network analysis package in RTDB in this paper.

Offline database is used for the following purposes in the developed microgrid EMS. The first is the data exchange between microgrid EMS and other centers. Figure 7 shows the configuration of the developed interface system and the flowchart of publishing data to the other EMS. The second is the storage of the long term data, for example, the historical or forecasted or calculated results of generation schedule and forecasting for over a few days. ACM in RTDB is used for only the data of applications within a few days in the developed microgrid EMS, and then the data out of a certain period are stored in offline database. The third is the compatibility of the data engineering tool by which the data are inserted, deleted, or edited.

**IEC 61850 Gateway**

Nowadays IEC 61850 becomes a standard for...
communication in medium voltage level of power system, especially, substation automation. However, Modbus is still generally used in communication of DER, so that it is anticipated that IEC 61850 gateway will be widely used in microgrid EMS for a while. The total system performance test of microgrid EMS with the developed IEC 61850 gateway is performed. Figure 9 shows the developed IEC 61850 gateway where the key mapping with DER’s manufacturer’s icd files and the environment of the gateway in xml file used in IEC 61850 stack of the gateway are configured by the gateway configuration tool.

**Microgrid Applications**

Generation applications package as shown in Figure 9 is developed for microgrid EMS. The applications are developed and implemented in accordance with ACM which is expressed in schema. Both of the offline database and RTDB are used for forecasting applications, generation schedule application, and demand response due to long term data. Only ACM is used for economic dispatch application and automatic generation control.

The developed applications are performed periodically. The filed data is measured every 2 seconds in microgrid EMS. Set points for AGC are calculated every 2 seconds and real control signals are transmitted every 4 seconds.

**Load Forecast and Renewables Forecast**

Both of electrical load forecasting and heat load forecasting are developed. From a different perspective of the forecasting horizon, load forecasting can be categorized into three classes, that is, very short term load forecasting (VSTLF), short term load forecasting (STLF), and medium term and long term load forecasting (MTLF and LTLF) [12], [13]. The developed forecasting applications are STLF and VSTLF. STLF is performed daily and produces a day or two days ahead forecast. The following first four conventional algorithms and one newly proposed algorithm named temperature sensitive short term load forecast (TSSTLF) in this paper are implemented.

- Moving average
- Exponential smoothing
- Decomposition
- Linear regression
- TSSTLF

Figure 10a shows TSSTLF, where the load sensitivity function is modelled as a quadratic function of temperature $T$ from analysis of historical load as shown in equation (1).

$$\begin{align*}
P_{i \text{max}}(T) &= a_{i \text{max}} T^2 + b_{i \text{max}} T + c_{i \text{max}}, \\
P_{i \text{min}}(T) &= a_{i \text{min}} T^2 + b_{i \text{min}} T + c_{i \text{min}},
\end{align*}$$

$i = \{\text{spring, summer, fall, winter}\}$

where $P_{i \text{max}}(T), a_{i \text{max}}, b_{i \text{max}}$ and $c_{i \text{max}}$ are load

![Figure 9: Process flow of generation applications package](image)

![Figure 10: Flowchart of Short Term Load Forecast and Very Short Term Load Forecast: (a) TSSTLF; (b) VSTLF using Pattern Recognition Algorithm by k-Means Clustering](image)
function and its coefficients using peak load at maximum temperature $T$ of season $i$, and $P_i^{min}(T)$, $a_i^{min}$, $b_i^{min}$ and $c_i^{min}$ are load function and its coefficients using off-peak load at minimum temperature $T$ of season $i$.

As the temperature is lower than the temperature at the symmetric axis of load sensitivity function, heat load is growing and more electrical generation is required for electrical heat appliances. In the contrast, as the temperature is greater than the temperature at the symmetric axis of load sensitivity function, heat load becomes smaller, but cooling load is growing and more electrical generation is required for electrical cooling appliances. The base maximum temperature at axis of quadratic function in summer and winter are typically 20°C and 12°C in Korea, respectively. Then, $\Delta P_i^{max}$ and $\Delta P_i^{min}$, or the difference at maximum and minimum temperature between the forecasted load and the historical load can be calculated as follows:

$$
\Delta P_i^{max} = P_i^{max}(T_{\text{new}}^{max}) - P_i^{max}(T_{\text{old}}^{max}),
\Delta P_i^{min} = P_i^{max}(T_{\text{new}}^{min}) - P_i^{max}(T_{\text{old}}^{min})
$$

where $T_{\text{new}}^{max}$ and $T_{\text{new}}^{min}$ is the maximum and minimum temperature at the forecasting day and they are given by weather center, and $T_{\text{old}}^{max}$ and $T_{\text{old}}^{min}$ is the maximum and minimum historical temperature at every previous one week to three weeks ahead same day as the forecasting day.

Then, the historical load can be modified by adding the difference as follows:

$$
P_i^{\text{max}} = P_{i,k} + \Delta P_{i,k}^{\text{max}}, \quad k = \{1,2,3\}
$$

$$
P_i^{\text{min}} = P_{i,k} + \Delta P_{i,k}^{\text{min}}
$$

where $P_{i,k}$ is the historical load at the same $k$ weeks ahead day as the forecasting day. Finally, the forecasted load $\hat{P}_i$ can be calculated as follows:

$$
\hat{P}_i^{\text{max}} = \frac{\sum_{k=1}^{3} P_{i,k}^{\text{max}}}{3}, \quad \hat{P}_i^{\text{min}} = \frac{\sum_{k=1}^{3} P_{i,k}^{\text{min}}}{3}.
$$

VSTLF is performed hourly or at least three times a day and produces a few hours ahead forecast. The procedure is explained in Figure 10b and the main algorithm is based on pattern recognition algorithm by k-means clustering in this paper [14], [15]. The same approach is applied to renewables forecast, that is, photovoltaic forecast or wind forecast. It will not be explained in further detail in this paper.

**Generation Scheduling**

The generation scheduling is to determine when DER operate or not, and how much DER produce the power to minimize the total cost of operation or to maximize the total benefit of selling power in a certain horizon [16], [17]. The proposed linearized objective function is as follows:

$$
\min_{x,t} \sum_{t \in \Omega} \sum_{i \in \Omega \setminus \{G_e, G_{chp}, G_h\}} x_{t,i} \text{Cost}_{t,i} + \sum_{t \in \Omega} \hat{P}_{\text{buy},t} \hat{P}_{\text{buy},t} - \sum_{t \in \Omega} \hat{P}_{\text{sell},t} \hat{P}_{\text{sell},t}
$$

where $x_{t,i}$ is binary variable (0/1) that represents the commitment state of DER $i$ at period $t$. $\text{Cost}_{t,i}$ is the linearized cost in block $b$ of DER $i$ at period $t$. $\hat{P}_{\text{buy},t}$ is the price of buying power at period $t$ and $\hat{P}_{\text{sell},t}$ is the price of selling power in tie-line at period $t$. $\tau$ is set of all period indices in scheduling horizon. $G$ is the set of indices of all DERs including cogeneration and ESS. $B_i$ is the set of all linearized blocks over the incremental costs of DER $i$. The objective function and its constraints are formulated as linear equations and linear inequalities. As a result, the conventional mixed integer programming (MILP) solver can be applied to the formulation. It will not be explained in further detail in this paper. The constraints of objective function are listed as follows:

- Demand supply balancing constraint
- Spinning reserve constraint
- Minimum up time and down time constraint
- Ramp rate constraint
- Minimum and maximum output constraint
- ESS constraint
- Interface line capacity constraint
- Linearized incremental costs boundary constraint

**ED and AGC**

ED is to determine only how much DER produce the power to minimize the cost of operation and to maximize the benefit of selling power at a time [18], [19]. The objective function is as follows:

$$
\max_p \hat{P}_{\text{buy}} \hat{P}_{\text{buy}} - \sum_{i \in \Omega} \text{Cost}_i
$$

for $\Omega = \{G_e, G_{chp}, G_h\}$

where $\text{Cost}_i$ is the operational cost of DER $i$ at a certain time, $G_e$ is the set of indices of all of the electrical DER, $G_{chp}$ is the set of indices of all of the cogeneration DER. $G_h$ is the set of indices of all of heat DER, e.g. boiler.
The constrains are almost same as generation schedule except the minimum up time and down time constraint and the initial condition of ESS constraint.

For synchronous parallel operation of DER and frequency restoration, the control using droop characteristics of DER, or AGC is shown in Figure 11 [21]. It should be noted that the solution of equation (6) which is calculated every a few minutes is $P_{\text{base}}$ in Figure 11.

Results of Field Tests and Discussions

Based on the proposed ACM structure, the developed microgrid applications are totally integrated into microgrid EMS together with IEC 61850 gateway. The performance test for mass of data processing of the special test network analysis application using ACM is conducted with about 100,000 points of pseudo measurements every 2 seconds, and it takes about 30 milliseconds enough to perform any other applications. The purpose of the field tests is to verify the stable operation of the proposed microgrid EMS using ACM together with IEC 61850 gateway through investigating the effect of AGC under various environments in the viewpoint of platform performance as well as in the viewpoint of the special application’s performance, or AGC. Then, the field tests for the fully integrated EMS is conducted at the two separate testbeds. Korea Electrotechnology Research Institute (KERI) testbed is designed for the tests in a scale of laboratory under various conditions with artificial dummy loads except some applications, e.g., generations schedule which make it take more computational time, and the microgrid demonstration site of Korea Electric Power Corporation’s Research Institute (KEPRI) is designed for the tests in a larger scale with the full applications.

Results of KERI Testbed

Figure 12 shows KERI testbed and the main DER are 50kW diesel generators (G50), 20kW diesel generators (G20), 10kW photovoltaic (PV), 10kW wind simulator (WT), 10kW fuel cell (FC) and 10kW lead acid energy storage system (ESS) which has bidirectional power conversion system with droop characteristic. Load 1, load 2, and load 3 in Figure 12 can be artificially controlled by the central dummy load simulator, respectively, to make different test conditions. The total installed capacity of all DER is 110kW, and the capacity of only controllable DER, that is, G50, G20, and ESS, is 80kW, or about 70% of total capacity.

Load test conditions are categorized into light (30%), medium (50%), and heavy (80%) load as shown in Table 1. While the average flow at PCC of Figure 12 is maintained to be 5kW, or about 5% of total installed capacity and when STS of Figure 12 becomes abruptly open to simulate the main grid blackout and microgrid will operate in off-grid mode, the tests for validation of the integrated system performance and effectiveness of AGC for frequency stabilization under off-grid mode are conducted. In light load condition, the excessive power output is assumed to be exported to the main grid for profit maximization under allowance of power trading, so that in case of 5kW flows at PCC, about 5% of full load, the test is performed when AGC function is activated or not. On the contrast, in heavy load condition, the insufficient power can be imported from the main grid. The frequency stabilization fails in all cases when AGC function is de-activated. Even when the average flow 0kW at PCC in medium load and AGC function is de-activated, the frequency stabilization fails.

Figure 13 shows the effectiveness of AGC by trend of the

Table 1. Results of Frequency Stabilization Test of AGC in Various Load and Flow Conditions at PCC

<table>
<thead>
<tr>
<th>Load Condition</th>
<th>Avg. Flow at PCC</th>
<th>AGC</th>
<th>Freq. Stabilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>30% of full load</td>
<td>5kW export</td>
<td>On</td>
<td>Success</td>
</tr>
<tr>
<td>30% of full load</td>
<td>5kW export</td>
<td>Off</td>
<td>Failure</td>
</tr>
<tr>
<td>50% of full load</td>
<td>0kW</td>
<td>On</td>
<td>Success</td>
</tr>
<tr>
<td>50% of full load</td>
<td>0kW</td>
<td>Off</td>
<td>Failure</td>
</tr>
<tr>
<td>80% of full load</td>
<td>5kW import</td>
<td>On</td>
<td>Success</td>
</tr>
<tr>
<td>80% of full load</td>
<td>5kW import</td>
<td>Off</td>
<td>Failure</td>
</tr>
</tbody>
</table>
actual output of DER, total load, and frequency. When AGC function is activated and before STS is open, or on-grid mode operation, the frequency deviation is maintained to be within 0.1%. When microgrid operates in off-grid mode, the frequency deviation will grow by 0.5%, or from -59.68Hz to 60.31Hz, but the frequency stabilization is successful as shown in Figure 13a. It should be noted that the load increases by 23%, or from 42kW to 55kW soon after the change of the operation mode from on-grid mode to off-grid mode. However, when AGC function is de-activated and STS is open, the frequency decreases abruptly to 0 Hz and all of DER will be tripped by each protection scheme as shown in Figure 13b. In this case, it should be noted that the load increases by 18.5%, or from 44kW to 54kW soon after the change of the operation mode from on-grid mode to off-grid mode, so that although the output of ESS increases by 10kW approximately, the frequency stabilization fails.

**Results of the demonstration site of KEPRI**

The test for the generation package of microgrid EMS is performed in the testbed of KEPRI, which is designed with two zones, zone A and zone B, for the specific purposes. The one is designed for the power quality test where 100kVA unified power quality controller (UPQC) is used for 100kVA sensitive loads, and the latter is designed for the generation package test where 82kVA diesel generator or diesel engine (DE), 60kVA micro turbine, a total of 70kVA photovoltaic (PV) and 50kVA, 50kWh battery ESS (BESS) are used for the minimization of the costs, or the maximization of the profits, and 96kVA load bank is used to make various load levels. Additionally, the virtual heat load is used instead of the physical one for the test of the generation package with the cogeneration.

When the outputs of all DER are constant in constant load condition long after the operation mode of microgrid is changed into off-grid mode, the tests are conducted with increasing abruptly adjustable loads for investigating the effect of AGC in off-grid mode. ESS has the characteristic of frequency restoration to the reference frequency [21]. The effect of AGC and frequency restoration of ESS are investigated under various conditions as shown in Table 2. In case 1, frequency regulation of ESS helps the frequency to be maintained within 0.43% of frequency deviation, or from 59.86Hz to 60.12Hz, during approximately twice stepwise 45% of full load change and the amount of load change is supplied mainly by ESS. In case 2 that both of AGC and frequency regulation of ESS are activated, the frequency is maintained within 0.46% of frequency deviation, or from 59.85Hz to 60.13Hz, during approximately twice stepwise 45% of full load change. The amount of frequency deviation is almost same that in case 1, but DG participates in supplying the electrical power
investigated during one stepwise load change because the frequency deviation is anticipated to be greater without ESS frequency regulation. In case 3, the frequency deviation is 1.1%, or from 59.35Hz to 60.03Hz during about stepwise 40% of full load change. ESS supplies mainly the amount of load change. In case 4, the frequency deviation is 1.4%, or from 59.5Hz to 60.32Hz, during approximately stepwise 44% of full load change and DG also participates in supplying the electrical power together with ESS unlike in case 3. The results show that AGC with frequency regulation of ESS is not effective enough, but AGC without frequency regulation of ESS is very effective when microgrid operates in off-grid mode and the amount of load change is significantly great.

**Conclusion**

This paper has presented the flexible RTDB platform and the generation applications package implemented on the proposed platform through ACM. The method to construct ACM can strengthen the flexibility of microgrid EMS for enlargement of application area of microgrid. In addition, the fast accessibility of RTDB will be effective for a large scale of microgrid with lots of DER and for the complex network analysis applications. The field tests for the total integrated EMS together with the developed IEC 61850 gateway, the CIM based web interface and the developed applications package, especially, ED and AGC, are performed. The results of the frequency regulation show that the proposed platform based totally integrated microgrid EMS is effective in the real fields. Furthermore, The method to distribute the grouped indices on the proposed RTDB platform is appropriate for multi microgrid environment, and the rearranged indices in ACM of the proposed RTDB platform is also appropriate for easy access of generation and network analysis applications package.

**References**


