Test Procedure – Collective power resource next day's generation by Multi-Scale LSTM Model

I. **Yearly Requirements:**

주요 성능지표		단위	최종 개발목표			기술개발전 수준	※세계 최고수준 또는 수요처 요구수준	전체항목에서 차지하는 비중(%)	평가방법
			1차년도	2차년도	3차년도				
VPP 분산자원 예측 및 최적화	집합전력자원 익일 발전량 시간대별 예측 오차율	%	-	≤10	≤8	12	8	10	2차:자체 시험 3차:공인 시험성적서

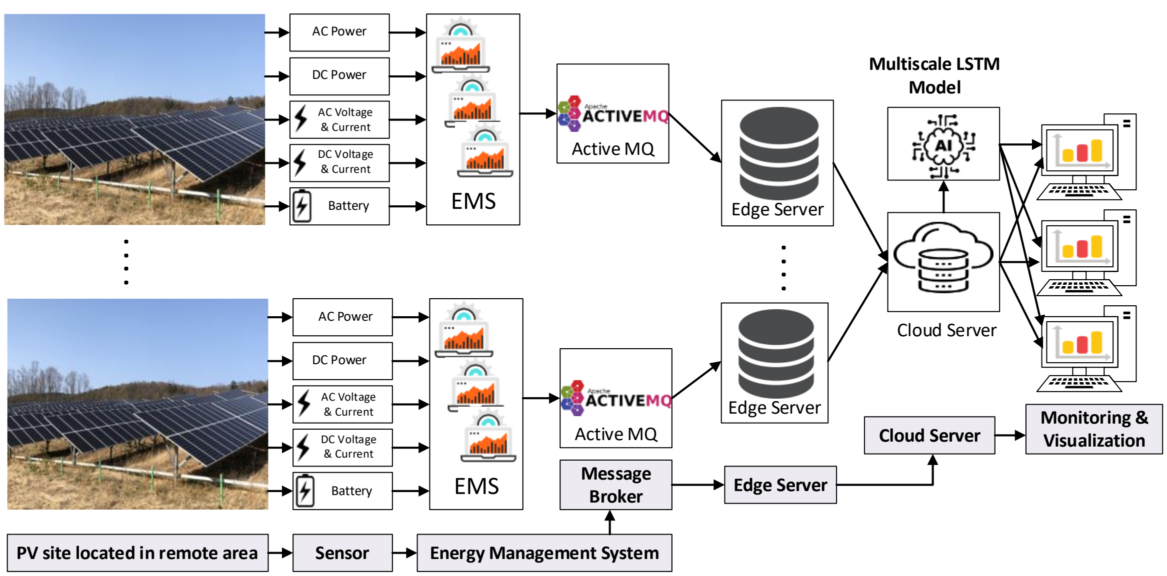
II. **Overall Architecture for Cloud Server**

• Step 1: Develop coding on the ActiveMQ platform side using Java.

• Step 2: ActiveMQ platform collects data from all sensors and stores in the PostgreSQL database.

• Step 3: Connect the python platform with the database system.

• Step 4: Apply Bi-directional long short-term memory (Multiscale LSTM) over the data and predict next-day PV power generation.



<Figure 1. Architecture for data acquisition from PV site to database system>

<Figure 1. Architecture for data acquisition from sensors to EMS>

$$D = (x_i, y_i)_{i=1}^{N}$$

Measurement procedure of collecting data and storing on the cloud server:

- All required sensors such as voltage sensor, current sensor, temperature sensor, and humidity sensor are connected to the energy management system (EMS) using TCP and Serial directly to the input module of EMS depending on each sensor connectivity.
- From the sensor, the PV generation data for each minute is calculated.
- The EMS collects all data from sensors continuously based on the sampling time of each sensor. Every minute, the EMS will transfer the collected data to the Cloud server using the MQTT protocol.
- To establish the MQTT connection between EMS and Cloud server, an internet connection is utilized.
- After receiving the data from EMS, the cloud server will store the data in its cloud database. In the cloud database, the data will be grouped into each type of data including the timestamp of the data. The database type that will be used is PostgreSQL.
- After that, the cloud server runs the AI algorithm for forecasting next-day PV generation using Multiscale LSTM. The result of the prediction is shown on the monitor.

Test environment and test method on the cloud server:

- The data from sensors were stored in a cloud database server for every minute.
- For the database, we will use PostgreSQL software because we did some tests using other database software and the result is PostgreSQL is the lightest and fastest among other database software.
- For testing and running the Multiscale LSTM software, we use work station with 64 GB of memory and Intel(R) Core(TM) i9-9820X CPU @ 3.30GHz 3.31GHz processors will be using the Windows Operating System.
- To run the AI algorithm, we use the most recent version of the Python programming language. We also use a few Python libraries to support AI algorithm development, such as Tensorflow, Numpy, Scikit Learn,

Pandas, and Matplotlib.

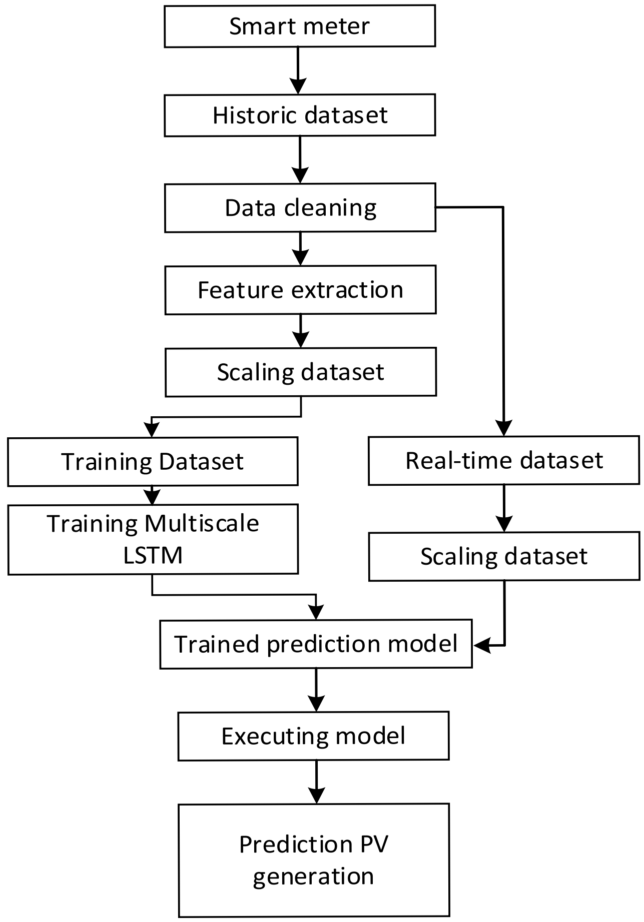
- Periodically, the system will do an AI training process using recent data received in the database. The training process will result in a trained AI model that will be used for the testing process (explained in Figure 3).
- Then, the new data will be loaded on the trained Multiscale LSTM model which will predict the real-time PV generation of the PV power station.
- The testing program will be in Python executable .exe file format. The cloud server will execute the .exe file to predict the energy generation in the system. Also, it will produce the mean error value of the prediction algorithm and print the forecasting result on the monitor.

III. Requirements and test scenarios

a. 2nd Year Requirements

b.

Model Name	KPI Metric	Target value 1st Year	Target value 2nd Year	Target value 3rd Year
Multiscale-LSTM	Mean	-	≤10%	≤8%



<Figure 3. Multiscale LSTM workflow.>

<Figure 4. Multiscale LSTM workflow.>

c. Multiscale LSTM model design and development:
   Step 1: Receive data through the database.
   Step 2: Select the feature.
   Step 3: Cleaning the raw data
   Step 4: Scaling and resampling the featured data.
   Step 5: Trained the Multiscale LSTM model.
   Step 6: To calculate the mean error rate of the system, we have applied this mathematical formula:

$$\text{Mean} = \frac{|\text{Annual forecast power generation} - \text{Annual measured power generation}|}{\text{Power plant capacity}}\ x\ 100\%$$

   Step 7: Save the model.

d. Scenario:
   Calculate and evaluate the error rate with the amount of power generation measured at three demonstration sites and the amount of expected power generation

The procedure of the proposed system evaluation of the Multiscale LSTM model

Step 1: Prepare the collective power resource generation raw test data of PV generation from the database.

Step 2: Cleaning and scaling the test data.

Step 3: Loaded the data in Multiscale LSTM saved model to determine the next day PV energy prediction.

Step 4: Measure the error NMAEE (Normalized Mean Absolute Error) for the difference from the actual measurement.

Step 5: Shows the forecasting results of the Multiscale LSTM algorithm.

The working procedure has been shown in Figure 3 and Figure 4.

c. Results and Discussion:

MSE: 661.6997
MAE: 11.3604
RMSE: 25.7235
r2: 0.8627

Key Performance Indicators	**Unit**	**Requirements**	**Current Status**
Mean Error	Percentage	**≤10%**	**9.819 %**

<Figure 5. Real time implementation results of Multiscale LSTM. >