Test Procedure – PV System Condition Detection

I. **Yearly Requirements:**

주요 성능지표		단위	최종 개발목표			기술개발전 수준	※세계 최고수준 또는 수요처 요구수준	전체항목에서 차지하는 비중(%)	평가방법
			1차년도	2차년도	3차년도				
VPP 시스템	시스템 이상 감지 정확도	%	≥92	≥93	≥94	90	92	5	1/2차:자체 시험 3차:공인 시험성적서

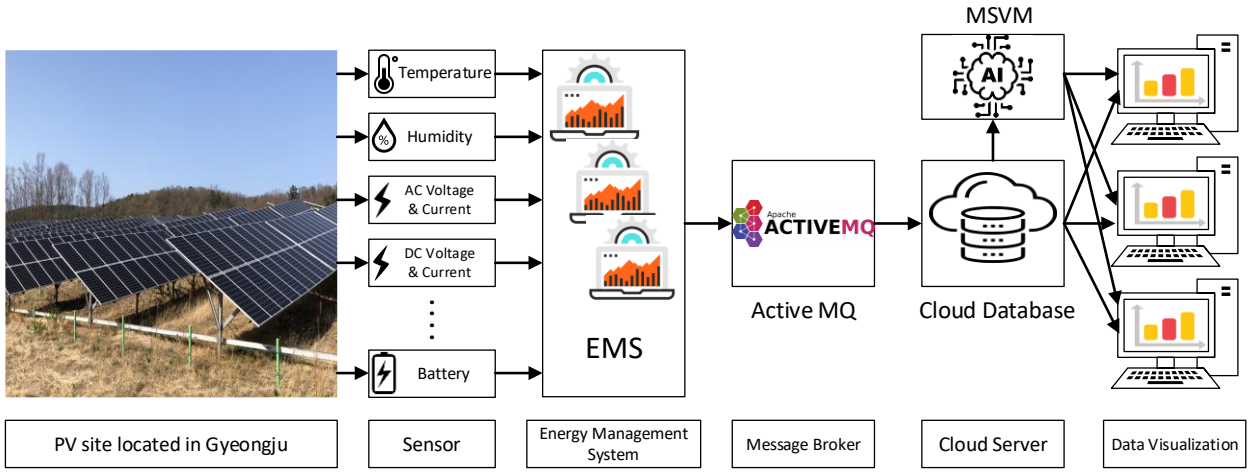
II. **Overall Architecture for Cloud Server**

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

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

• Step 3: Connect the python platform with data base system.

• Step 4: Apply multi-class support vector machine (MSVM) over the data and detect system abnormality conditions.



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

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

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

- All required sensor such as voltage sensor, current sensor, temperature sensor, and humidity sensor are connected to energy management system (EMS) using TCP and Serial directly to the input module of EMS depends on each sensor connectivity.
- The EMS collects all data from sensors continuously based on sampling time of each sensor. Every one minute, the EMS will transfer the collected data to the Cloud server using MQTT protocol.
- To establish the MQTT connection between EMS and Cloud server, internet connection is utilized.
- After receiving the data from EMS, the cloud server will store the data to 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 abnormality detection using MSVM. The result of the detection is shown in monitor.

Test environment and test method on the cloud server:

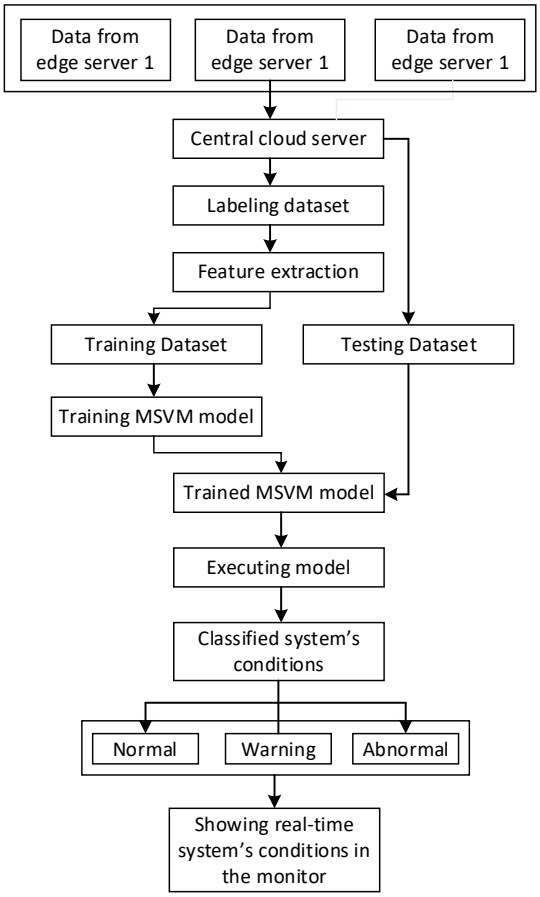
- The data from sensors were stored in cloud database server for every one minute.
- For the database, we will use PostgreSQL software because we did some tests using other database software and the result is PostgreSQL is lightest and fastest among other database software.
- For testing and running the MSVM 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 the AI algorithm development, such as Tensorflow, Numpy, Scikit Learn, Pandas, 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 newly data will be loaded on the trained MSVM model which will detect real-time abnormal condition of the PV system.

- The testing program will be in Python executable .exe file format. The cloud server will execute the .exe file to detect abnormality in the system. Also, it will produce the accuracy value of the detection algorithm and print the detection result in the monitor.

III. Requirements and test scenarios

a. 2nd Year Requirements

Key performance Indicators	Unit	Requirements	Current Status
System conditions detections by SVM	Percentage	**≥93%**	**93.42 %**



<Figure 3. MSVM workflow.>

b. MSVM model design and development:

Step 1: Receive data through database.
Step 2: Select feature through feature selection algorithm.
Step 3: Labeling dataset into three categories as follows:

Parameter	Condition	Range of parameter
Voltage (System Conditions by MSVM)	Normal	397V—403V
	Warning	403--406V and 394—397 V
	Critical/Abnormal	>406V and <394V

Step 4: Scaling the featured data with standard.
Step 5: Trained the MSVM model.
Step 6: To calculate the accuracy of the system, we have applied this mathematical formula:

where, number of correct predictions = Number of true positive (TP) + Number of true negative (TN)
Total number of predictions = Number of true positive (TP) + Number of false negative (FN)+ Number of true negative (TN)+ Number of false positive (FP)

Step 7: Save the model.

c. Scenario:
Procedure of system abnormal conditions detections by MSVM
Step 1: The sensor sends the data in real time.
Step 2: Receive real-time data through database.
Step 3: Loaded the real-time data in MSVM saved model to determine the system abnormal conditions.
Step 4: Shows the real-time results of the MSVM algorithm.

The working procedure has been shown in Figure 2.

c. Results and Discussion:

< Figure 4. Sample of data at different condition. >

<Figure 5. Real time implementation results of MSVM on cloud server. >

<Figure 6. Evaluation results of MSVM. >