Method and Device for Voltage Stability of ITS roadside controller with Blocking Leakage Current

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ABSTRACT

A lot of ITS (Intelligent Transportation System) devices have been installed at roadside to collect traffic volume, travel speed, video, etc. The RSE (Roadside Equipment) is installed at the road shoulder and operated by receiving electricity from an ambient transformer. However, the input electricity to RSE is being provided unstably because of the physical distance between RSE and transformer, fluctuations around the electric power load etc. Generally, RSE has a device that rectifies unstable input electricity. However, when the input voltage is changed significantly, it exceeds the conversion range of a voltage converter and affect the controller. In this study, we propose a method that provides stable voltage for unstable input voltage and present the result of improvement scheme through the experimental study for the developed device.

Keywords: *Power instability, Voltage converter, ITS, RSE*

1. INTRODUCTION

In Korea, a traffic survey has been conducted in order to maintain the road and traffic database is utilized for road planning and construction, pavement, improvement of traffic safety and research related to road. As of 2001, a total of 534 RSEs that collects vehicle types and traffic volume has been operated on national highway in Korea. RSEs are collecting traffic information continuously and transmitting the data to the server in real-time through networks 365 days a year. As the RSEs are exposed to the outside for a long time, deterioration and breakdown of electronic devices occur frequently according to the weather condition. Moreover, RSEs use a commercial power supply of 220V from the transformer nearby. At this moment, the input voltage that is supplied to the RSEs might be unstable because of weather condition, electrical load condition and so on. The existing steel roadside cabinets are vulnerable to the external environment such as dust, moisture, deicers etc., and as time goes by, these external factors can aggravate the corrosion of the cabinet. Therefore, it is necessary to develop a corrosion-resistant cabinet.

As being exposed to outdoors for a long period, the steel cabinets are painted off and also an electric leakage of inner power device leads to electric shock in the case of being touched with a pedestrian's body. Accordingly, reinforcement of a protection circuit function is needed to detect an electric leakage in the dual and cut off the power. RSEs are installed in the middle point, applying the interval defined by the country and the number of the selected sections for installation is 620 for large sections and 1,600 for small sections respectively. However, RSEs has been installed in the large sections only. Because the number of locations to be managed becomes larger in order to implement RSEs in the small sections, RSEs are required to have much higher work stability. Therefore, the purpose of this study is to develop a device for stability improvement of RSE voltage module and to conduct a performance experiment.

In general, road surface observation is conducted using CCTV or patrol with the naked eye. Even though there is a method of using a sensor buried in the road surface at specific point, it is almost impossible to control a wide area because of the high initial cost for installation and maintenance.

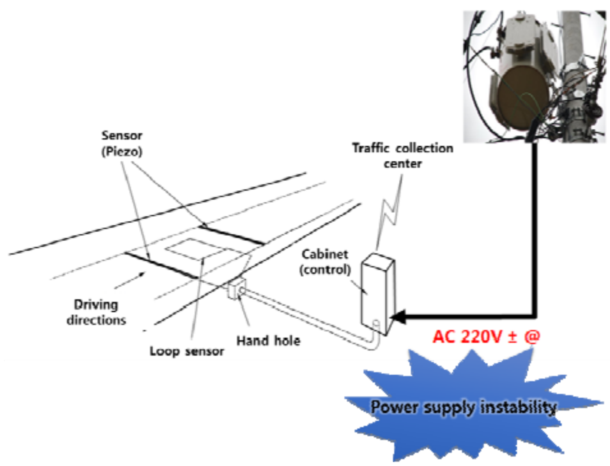

Fig 1: Common installation method of RSE

As shown in Figure 1, since the power for RSE is supplied from ambient transformer, several problems happen due to unstable power supply and climatic change. In this study, the RSE power supply module convert external AC power to stable DC power for operating the device. The MMI and the LED are in front of the power module and the auxiliary storage battery is inside to prepare charge, discharge, and power failure. If the input power is not supplied, the power of the secondary battery would be provided to the device in order to operate it by using DC/DC power converter. In this way, as a power supply board of RSE is built for high frequency and the internal circuit is separated, stable and efficient power supply is assured rather than before.

2. REVIEW ON PREVIOUS STUDIES

2.1 Review on Existing Research

Lim et al. [1] designed a power stability device of a roadside controller buried on the road, which has the structure of an electromagnetic sensor array. Their scheme uses a buried inductance coil that generates electromagnetic fields, and by supplying the micro current, electromagnetic fields are generated. The sensor generates a frequency of 10 kHz to 200 kHz in order to form a uniform induced magnetic field. The vehicle and speed are detected when a vehicle passes over an induced magnetic field through observing slight magnetic variation. The inductance coil forms an induced magnetic by sending energy having specific frequency to the inductance coil through an incoming line, and the magnetic flux changes depending on vehicle's passing, and then the magnetic flux variation changes inductance.

In Korea, a roadside controller measuring the traffic follows a modified installation guideline based on the American national standard. Most of the devices have RSE structure based on inductance contain an inductance coil sensor, an incoming line, and a roadside controller [2]. These RSEs are used for traffic survey, and some of them are applied to ITS with data fusion [3]. In some studies, measurement devices for bridges and structures are used, and the measuring device directly installed on road facility uses its own power conversion device [4]. It is necessary for a roadside controller to control a stable output power according to power supply condition. However, there are a few researches in terms of power supply stabilization.

2.2 Fault types of Existing RSEs

The power stabilizer of RSE having a buried sensor array structure consists of a protective circuit module, a resonant oscillator circuit module, a frequency evaluation module, and a CPU module. The existing RSEs have damage around sensor by being exposed to road surface and vehicles for a long term. Since the power for RSE is supplied from ambient transformer, several problems happen due to unstable power supply and climatic change.

The failure of RSE occurs frequently because RSE is exposed to weather conditions. As the main results of analyzing the cause of failure in 2010 and 2011, the power and communication defect accounted for approximately 80%. Moreover, the power supply defect occupied a large portion, and the problem occurred that the equipment does not work temporarily because of unstable power supply besides not working by cut off of power supply.

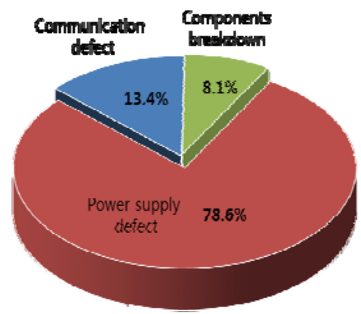

Fig 2: Fault types of RSEs (2010~2011)

This study focused on power supply defect occupied the largest portion of faulty types, and examined the method that minimize failure causes according to unstable power supply and temperature-humidity conditions. The existing steel roadside cabinets are vulnerable to the external environment such as dust, moisture, deicers, etc. and these external factors can aggravate the corrosion of the cabinet. The corrosion leads to electric shock and costs for maintenance cause economic loss. In order to reduce the number of electric shock, a circuit detecting leakage current is attached inside the cabinet.

3. METHOD OF POWER STABILIZATION CORRESPONDING TO POWER NOISE

3.1 Method of Power Supply Stabilization

The purpose of this study is to improve RSE by suggesting power supply stabilization methods. To achieve this, a control module was developed to correspond to the power source instability and the weather conditions. Firstly, the requirements for power supply module were defined, and based on this, power conversion module was suggested. RSE has malfunction when the abnormal current called noise flows into the power, and this situation leads to breakdown. Thus, as countermeasures of power noise, the process for detecting an abnormal current of the power supply is needed, and the power-off and initialization functions are required.

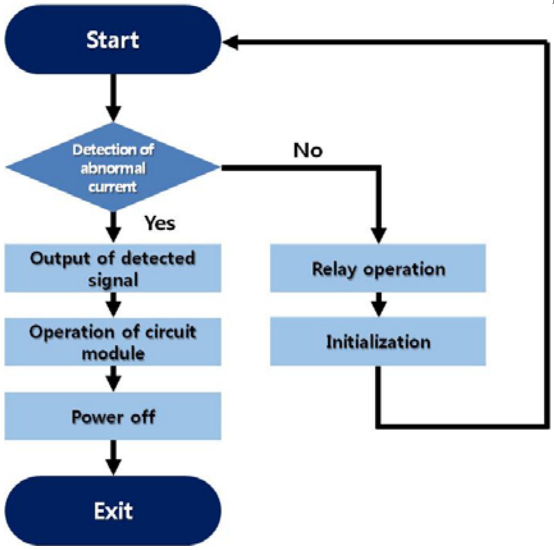

Fig 3: Noise detection and response procedures

3.2 Design of Power Control Converter against Noise

The RSE power supply consists of dual power converter with two AC/DC powers. The proposed RSE power supply can cover from AC 170V to AC 260V, wider than existing RSEs. Dual AC/DC powers have AC input. The first AC/DC power is used for main control part and supplies power to DC/DC power, and the second AC/DC power charges using a storage battery.

In order to prepare for external power supply instability, the requirement of RSE power converter was defined as follows. Input voltage range are AC 170V to AC 260V±10%, Output characteristic is DC 5V with DC±12V±1%, and frequency is 60Hz±3Hz. Variation rate is required to be less than 2% of the output voltage when the input voltage changes at the output of the maximum load regulation. Also, load variation rate is required to be less than 5% of the output voltage when current of output load changes from minimum to maximum.

3.3 Leakage Current Detection and Voltage Stabilization Method

A circuit for detecting leakage current is included in a RSE, and the reference value is set to 15mA for detecting leakage current. If the value of leakage current is greater than threshold, power would be off and the operating conditions are expressed on a display part. If the AC input power is unstable, a detection unit detects the problem. At the same time, a surge detection unit decides whether it is surge or not, based on comparison, and if it is decided as surge, LED turns on. When the power supply is unstable, it is sent to DC power switching portion through a power filter unit and a power input rectifier. The power switching generates the rated voltage by switching to 5V DC and 12V DC. At this time, leakage current is measured in the leakage current section, and LED turns on when the value is different from threshold.

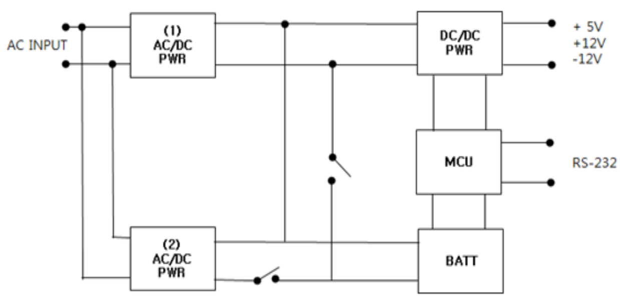

Fig 4: Dual power converter

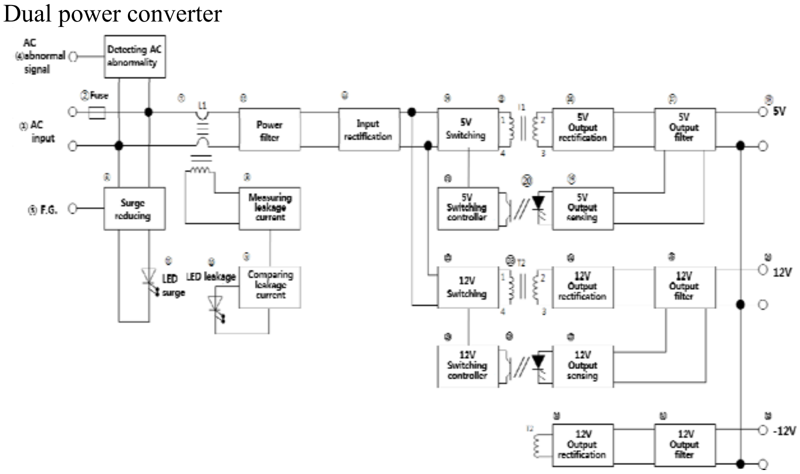

Fig 5: Block diagram of circuit for detecting leakage current and output voltage stabilization

3.4 Power-off and Recovery Methods of Controller from External Noise

A power supply device converts AC power to stabilized DC power in order to supply the power to the controller. It is possible to radiate heat by natural ventilation, and it operates stably even though of input and load changes. There is a fuse to protect the system against internal and external problems, and the output connect of power supply device is designed to withstand the capacity of the power supply.

When the AC power is input, the circuit that detects the abnormal current works in the filter unit. If the abnormal current is generated, the detection signal is output, and the power is turned off with operating of a circuit module that cut off leakage current.

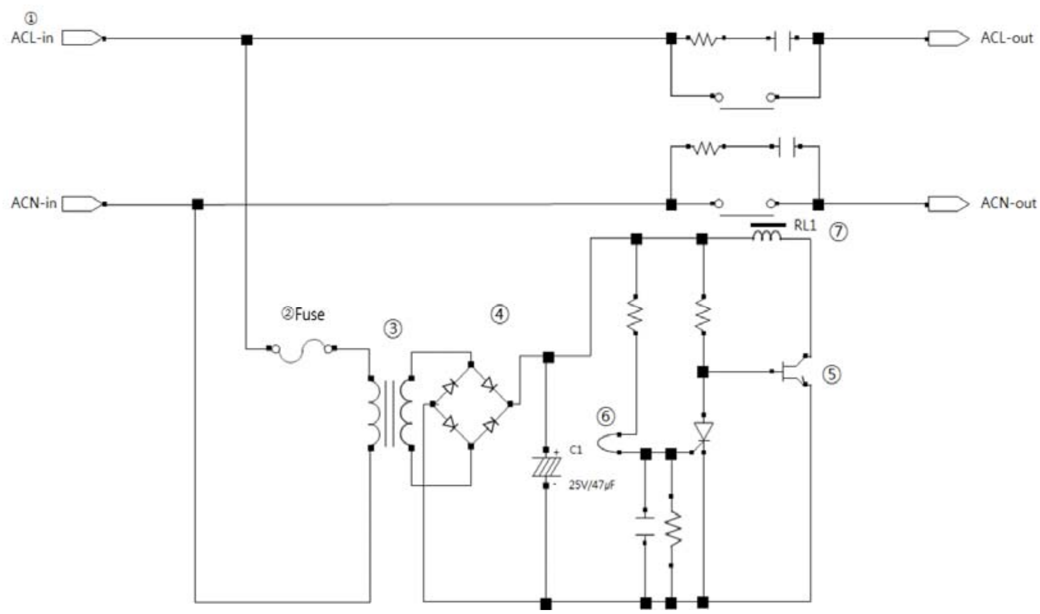

Fig 6: Power-off and recovery methods of controller from external noise

4. DEVELOPMENT OF POWER STABILIZAER FOR RSE AGAINST NOISE

4.1 Specification of Power Stabilizer

Power stabilizer of RSE controller was designed to have load variation rate of 10 to 100% and input voltage variation rate of 100% to output condition. Also, over current protection function of controller was designed to be operated for 120% to the rated output and have more than 80% efficiency at the rated condition. Surge voltage was tested at 2kv and 4kv for withstand voltage test and operating circuit for leakage current was designed to detect 15mA or more.

Power stabilizer of RSE controller converts input AC power into stabled DC power and supply it to controller. Also, it can radiate heat by natural ventilation and be operated even though of input and load variations. Front display part of power supply has LED display to check with the naked eye whether the output voltage is being output normally or not. Power supply has a fuse which is installed and can be replaced to protect a system against problems occurring both internally and externally.

The rated outputs are DC 5.0V 10A, +12V 10A, and -12V 2A according to AC input conditions (110V/220V 60Hz), and maximum output power is 200W. Over current protection is operated for 120% or more to the rated output. It has 80% or more efficiency at the rated condition, and ripple and noise is within maximum of 200mV. The condition of withstand voltage test was to bear it for one minute at AC 1500V 10mA. Also, leakage detection test was to detect 15mA or more.

The detailed specification of new power regulator is summarized as Table 1.

Table 1: Specification of new power regulator

Item	Content
AC Input condition	AC 110V/220V 60Hz
Rated output condition	DC 5.0V 10A, +12V 10A, -12V 2A
Max. output power	200W
Ambient temperature	-25□ to 70□
Relative humidity	Max. 90%
Cooling type	Natural convection air cooling
Input voltage variation rate	100% to output condition(for input voltage variation)
Load variation rate	10% to 100% to output load condition
Over current protection	Operating for 120% or more to the rated output
Efficiency	80% or more at the rated condition
Ripple and noise	Max. 200mV
Insulation resistance	DC 500V 10MΩ or more

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test	
Surge	Line to line 2kV, line to ground 4kV
Withstand voltage test	1minute test for AC 1500V 10mA
Leakage detection test	15mA or more

Power stabilizer using leakage detection circuit was developed through PCB/part assembly and case assembly after circuit design, part and circuit development, and test process, as shown in Figure 7.

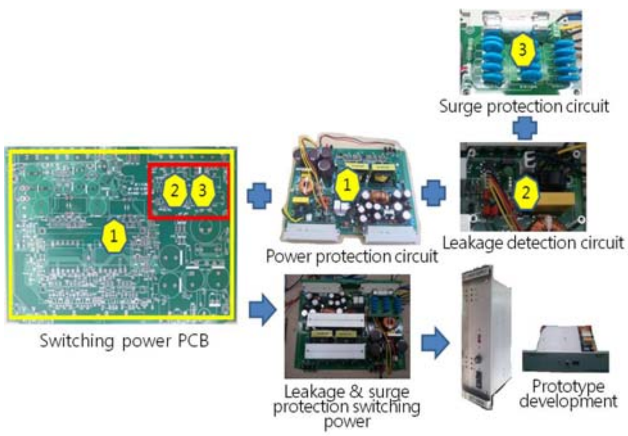

Fig 7: Power supply module with built-in leakage detection circuit

4.2 Test Methods and Suitable Criteria

The tests that were conducted for voltage stabilization of roadside controller can be divided into several tests. Firstly, we conducted voltage stabilization rate test that confirm whether output voltage is kept within acceptable range or not according to input voltage variations. Suitable criteria of voltage stabilization rate test are set as +5.0V±2%, +12V±2%, and -12V±2%. Secondly, we conducted load current stabilization rate test that confirm output voltage according to change of output such as 10%, 50%, and 100% load condition. Suitable criteria of it are +5.0V±2%, +12V±2%, and -12V±5%. And then, we conducted over current protection test that confirm whether power is protected or not through current limit protection circuit when a current over the prescribed flows. Also, we conducted power efficiency test. For this test, we measured voltage and current values of output according to change from input voltage (220V) to 100% load and calculated the power consumption in this state. Power efficiency is calculated as follows.

$$\text{Power efficiency}\ (\%) = \frac{\text{output power}\ (P_o)}{\text{input power}\ (P_i)} \times 100$$

If power efficiency is more than 75%, it is judged to be appropriate. Finally, we conducted ripple and noise test. Since power stabilizer is a high frequency switching type, if countermeasure to noise is not considered, it shows the characteristics of DC output with a lot of ripple and noise. Suitable criteria of it are 100mV for ripple and 200mV for noise, respectively.

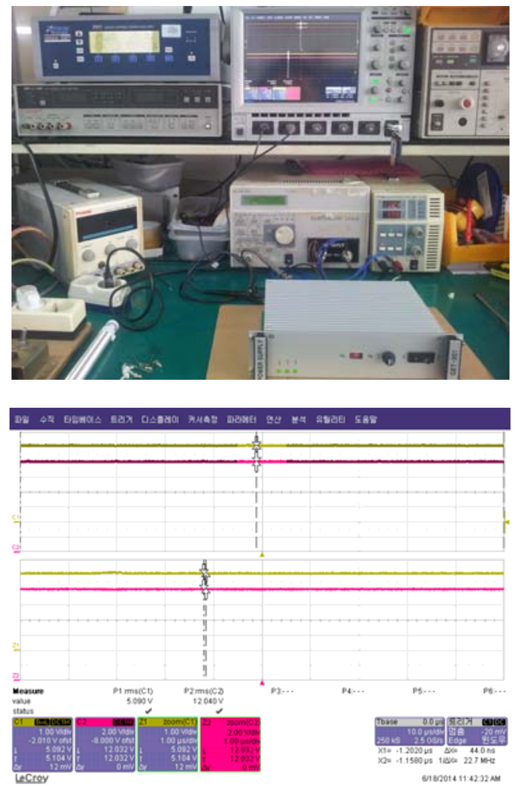

Fig 8: Test equipment arrangement and scope Meter measurement result

4.3 The Results

For testing RSE output characteristics, we compared the performances of the existing power supply devices A and B [1], and prototype C developed in this study according to load changes such as 10%, 50%, and 100%.

Figure 9 shows voltage stabilization result by type according to load changes. At 10% of load condition, there is not much difference among A, B, and C as 5.09V/12.091V for A, 5.131V/12.111V for B, and 5.118V/12.116V for C, respectively. At 50% of load condition, output voltages are within stable range as 5.068V/12.091V for A, 5.13V/12.111V for B, and 5.12V/12.116V for C, respectively. Also, at 100% of load condition, output voltages are within stable range as 5.087V/12.033V for A, 5.132V/11.898V for B, and 5.121V/12.082V for C, respectively. However, A type has relatively large variation of output voltage characteristics according to load conditions since a load switching power device of A type have higher noise sensitivity according to load changes due to not having circuit against noise.

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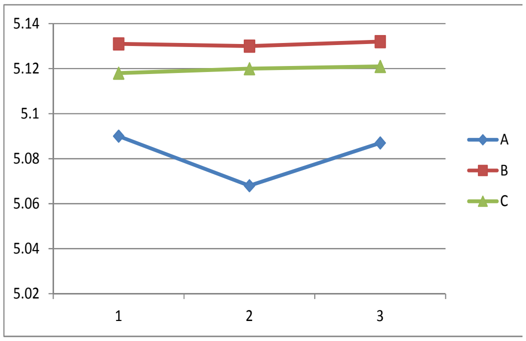
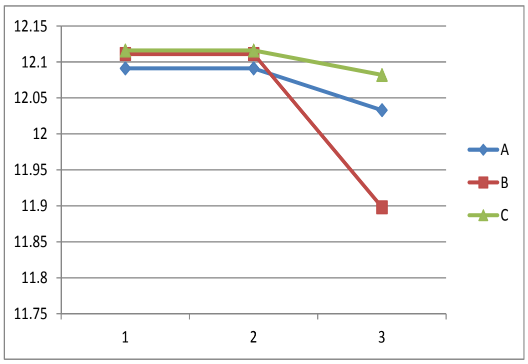


(a) 5V output voltage characteristics



(b) 12V output voltage characteristics

Fig 9: Voltage stabilization results (1: 10% load, 2: 50% load, 3: 100% load)

As a result of power efficiency comparison among A, B, and C based on RSE output characteristics like Figure 10, it shows that the prototype that was developed in this study is superior to others as 67.5% for the power efficiency of A, 63.6% for the power efficiency of B, and 81.4% for the power efficiency of C, respectively.

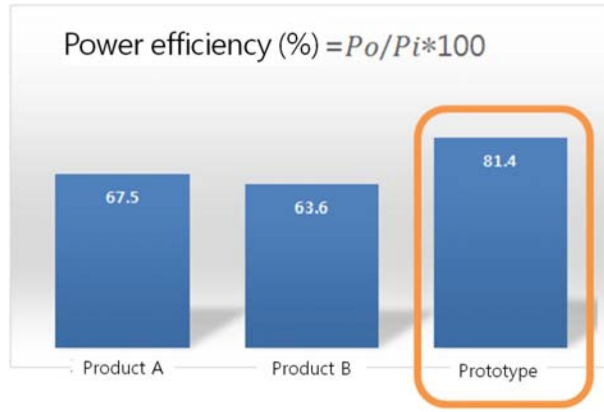


Fig 10: Power efficiency comparison

Table 2: Result of power stabilization comparison

Type	A	B	C
Stabilization rate of input voltage (%)	-0.37,-0.43	-0.038,-0.019	-0.019,+0.039
	-0.058,-0.058	-0.025,-0.008	+0.041,-0.124
Stabilization rate of load current (%)	1.034	0.194	0.621
	0.479	1.758	0.28
The state of output voltage	Peak occurs intermittently	Peak occurs intermittently	Stable
Efficiency (%)	67.5	63.6	81.4
Function of leakage current blocking	None	None	15mA
DC output capacity	5V 20A, 12V 5A	5V20A,12V5A	5V20A,12V10A

5. CONCLUSION

In this study, we implemented efficient and stable power supply devices using high-frequency RSE power board and separating internal circuits. Also, we designed the module that can prevent electric shock by configuring a method and circuit for detecting leakage current and validated the performance of the proposed device through experiment dat.

Through the proposed method, the safety of RSE operation and utilization of RSE can be enhanced by improving output voltage stabilization and the method of detecting leakage current that is the problems of on-site devices. Also, maintenance burden can be improved by reducing the number of on-site inspections for unstable power supply.

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