STUDY ON CLOUD-DUST BASED FOOL-PROOFING DESIGN AND CRISIS MANAGEMENT FOR MAINTENANCE OF SOLAR ENERGY GENERATING SYSTEM

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Abstract- In the paper, a cloud-dust based fool-proofing design and crisis management for maintenance of solar energy generating system is proposed. It is designed to prevent the failure of the various intelligent mechanisms of solar energy generating system, including records, surveillance, assessments, predictions, diagnosis, prescription, and scheduling. It is implemented based on cloud-dust architecture.And it is separated into (1) fool-proofing design module (2) crisis management module. The fool-proofing indexes are set to prevent the failure of the various mechanisms. The states of the various mechanisms are managed by the auto-checked fool-proofing indexes. If mistakes prevention is fail, we have to execute the crisis management for stopping harmful results. The crisis management will find the error level and response the solution by intelligent Inference. The computing engines of the intelligent system model are designed using neural network, fuzzy logic and particle swarm optimizationmethod.By the experiments, we can find the advantages of the proposed system. And it is effective to prevent the failure of the various mechanisms of intelligent solar energy generating system.

Keywords- Cloud Computing,Fool-Proofing, Crisis Management,Intelligent Maintenance,Solar Energy Generating System.

I. INTRODUCTION

Due to the shortage of energy, renewable energy becomes more and more important. With the green energy more attentions, developing of solar energy generatingsystems is more and more flourishing.For preventingfailure of intelligent automation systems, it is more important for developing fool-proofing design and crisis management of solar energy generating systems. In 1993, Paul A. Hutchinsonet al.[1]develop utility-grade operations and maintenance program for PVUSA (Photovoltaicsfor Utility Scale Applications). Operations and maintenance documentation and procedures, operational experiences, lessons learned, and conclusions are presented.In 1997, Takashi Hiyama et al. [2]presents an application of an artificial neural network for the estimation of maximum power generation from PV module. The output power from a PV module depends on environmental factors such as irradiation and cell temperature. The proposed method gives highly accurate predictions compared with predictions using the conventional multiple regression model. Irradiation, temperature and wind velocity are utilized as the input information to the proposed neural network. The output is the predicted maximum power generation under the environmental factors. By using actual data on daily, monthly and yearly bases, the efficiency of the proposed estimation scheme is evaluated. In 2002,I. Morsy et al. [3] presents an on-line prediction technique of the photovoltaic output power under cloudy skies based on artificial intelligence. The advantage of the fact that fuzzy logic can accurately simulate nonlinear phenomena using a set of IF-THEN rules. These rules are fired partially and in-parallel. This means that only a very limited subset of the rules is used at any time. It enables a quickon-line estimation of the output power of the photovoltaic cells based on the analysis of the image of the cloudy sky. In 2010, Jake Jacobi et al. [4] proposed the solar PV plant operational support model and provides the reader with insights into developing a solar PV operating model from a variety of choices.The model addresses the mechanical and electrical needs of the plant as well as maintaining the grounds and communication systems. In 2010, LoredanaCristaldi et al.

[5] proposed a remote monitoring system for on-line tracking of the energy performance of a photo-voltaic generation plant. Some experimental results on a lab prototype are discussed. The system contains DAQ, MySQL, Human Machine Interface. In 2010, Yuehui Huanget al. [6] proposed two power forecasting methods for PV systems, physical method and statistical method, are studied. A physical model based on the construction of PV systems and a NN statistical model based on historical data are set up. The impacts on forecasting accuracy of input data, such as air temperature, cloud, solar irradiance, humidity and sun position, for these two models are presented. And best input data models are built up for these two methods. Finally, the comparison of performance of the two forecasting models is investigated by a case study of a 1MW PV station. Moreover, by comparison, the main origin of forecasting errors comes from the accuracy of weather prediction information was found. Future improvement of power forecasting methods mainly relies on improvement of weather forecast in short-term forecasting application. Furthermore, real-time measured irradiance data can be considered to modify

the model input to further improve super-short-term forecasting performance.

II. CLOUD-DUST BASED ARCHITECTURE

The cloud-dust based architecture is separated to the cloud system and the dust system. The cloud system is consist of SQL database and cloud computing systems. The dust system is consist of Zigbee and embedded systems. The cloud-dust based architecture is showed in figure 1.

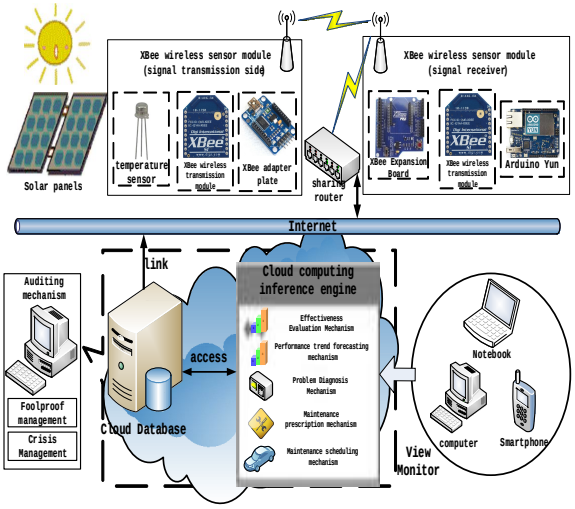


Fig.1. 2. Cloud-Dust Based Architecture.

(1)The Dust System

The parameters of solar energy are listed in table 1. Pdc、Vpv、Ipv、Irrwas wireless transmission by XBee module and Ardunio Yun. It is showed in figure 2.

Table1:The parameters of solar energy

Variable name	
Pdc：Photovoltaic Power	
Vpv：Photovoltaic Voltage	
Ipv：Photovoltaic Current	
Irr：Irradiance	
Tm：Module Temperature	
Ort：Orientation	
Mta：Tilt angle	
Equipment	Pmax：Maximum Power
Specifications	Vpm：Maximum Power Voltage
	Ipm：Maximum Power Current
	Voc：Open Circuit Voltage
	Isc：Short Circuit Current
	ηm：Module Efficiency
	Pmtc：Temperature Coefficient of Pmax
	Tn：Normal Operating Cell Temperature

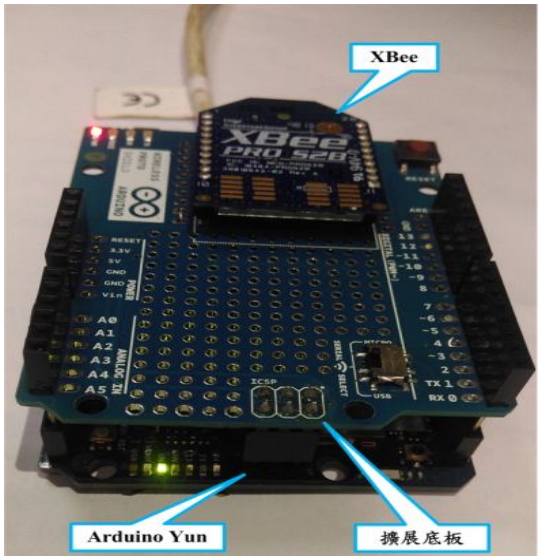


Fig.2. XBee :wireless transmission module

(1)The Cloud System

The cloud system consist of Web-based HMI Microsoft Windows Azureand Windows Azure SQL Database. The architecture of cloud database is shown as figue3.

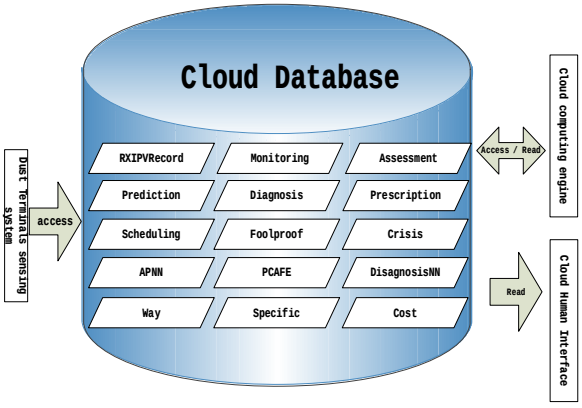


Fig.3. Architecture of cloud database.

The cloud computing engine, including PCA neural network, PSO algorithm, is designed with Visual C# and ASP.NET. It showed In Figure 4.

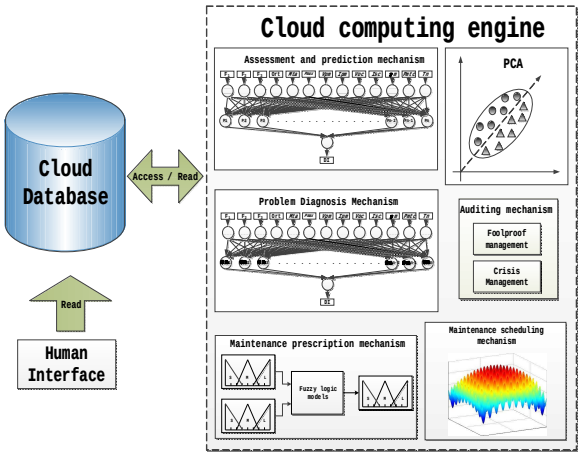


Fig.4. Architecture of cloud computing engine

III. DESIGN OF COMPUTING ENGINES

(1)Fool-Proofing Design

The fool-proofing indicatorsare showed in table 2. For preventing mechanisms of record, monitoring, assessment, prediction diagnosis, prescription and scheduling, the auxiliary mechanism preliminary audit information will be checked.

Table2:Parameter meaning of fool-proofing

Parameter name	Parameter meaning
Ir： Record Fool proofing Index	Records time fool proofing check index
Im： Monitoring Fool proofing Index	Monitoring data contentfool proofing check index
Ia： Assessment Fool proofing Index	Inference system assessmentfool proofing check index
Ipd： Prediction Fool proofing Index	Inference effectiveness prediction fool proofing check index
Id： Diagnosis Fool proofing Index	Inference issue diagnosis fool proofing check index
Ips： Prescription Fool proofing Index	Inference maintenance prescription fool proofing check index
Is： Scheduling Fool proofing Index	Inference maintenance scheduling fool proofing check index

And the standards of the check arelisted in table 3 and table 4.

Table3:the standards of the check

Parameter name	Mechanism	Parameter meaning
Ir_1	Record	variables Determine whether loss
Im_1	Monitoring	variables Determine whethe is 0
Im_2		variables Pdc、Vpv、Ipv、Irr、Tm Determine whether is greater than the maximum
Im_3		variables Pdc、Vpv、Ipv、Irr、Tm Determine whether is less than the minimum
Im_4		variables Pdc、Vpv、Ipv、Irr、Tm Compared with the before value, Determine whether is the error is large
Im_5		variables Pdc、Vpv、Ipv、Irr、Tm Compared with the before value, Determine whether is the error is equal
Ia_1	Assessment	Variables Mse Determine whether is less than the minimum
Ia_2		Variables Mse Determine whether is greater than the maximum
Ipd_1	Prediction	Variables Trend Determine whether is less than the minimum
Ipd_2		Variables Trend Determine whether is greater than the maximum
Id_1	Diagnosis	variables DI Determine whether is greater than the maximum
Id_2		variables DI Determine whether is less than the minimum
Ips_1	Prescription	variables MT Determine whether is greater than the maximum
Ips_2		variables MT Determine whether is less than the minimum
Is_1	Scheduling	variables MS Determine whether is repeat

Table4:Indexes of fool-proofing model

Auditing mechanism	Indicator variables	Audit variables	Audit indicator values
Record	Ir_1	表 2-1 紀錄時間	$Ir_1=2$
Monitoring	Im_1	表 2-1 全部	$Im_1=0.0$
	Im_2 Im_3 Im_4	Pdc	$Im_2=0.25$, $Im_3=0.02$, $Im_4=Pdc_{n-1}$
		Vpv	$Im_2=0.50$, $Im_3=0.30$, $Im_4=Vpv_{n-1}$
		Ipv	$Im_2=0.065$, $Im_3=0.005$, $Im_4=Ipv_{n-1}$
		Irr	$Im_2=0.45$, $Im_3=0.07$, $Im_4=Irr_{n-1}$
		Tm	$Im_2=0.07$, $Im_3=0.01$, $Im_4=Tm_{n-1}$
	Im_5	Ort	$Im_5=Ort_{n-1}$
		Mta	$Im_5=Mta_{n-1}$
		Pmax	$Im_5=Pmax_{n-1}$
		Vpm	$Im_5=Vpm_{n-1}$
		Ipm	$Im_5=Ipm_{n-1}$
		Voc	$Im_5=Voc_{n-1}$
		Isc	$Im_5=Isc_{n-1}$
		ηm	$Im_5=\eta m_{n-1}$
		Pmtc	$Im_5=Pmtc_{n-1}$
		Tn	$Im_5=Tn_{n-1}$
Assessment	Ia_1, Ia_2	Mse	$Ia_1=0.0$, $Ia_2=0.01$
Prediction	Ipd_1, Ipd_2	Trend	$Ipd_1=0.0$, $Ipd_2=0.01$
Diagnosis	Id_1, Id_2	DI	$Id_1=0.0$, $Id_2=1.0$
Prescription	Ips_1, Ips_2	MT	$Ips_1=1.0$, $Ips_2=11.0$
Scheduling	Is_1	MS	$Is_1=MS_{1,2,3,\ldots,n-1}$

The flowchart of fool-proofing model for records is shown as figure 5.

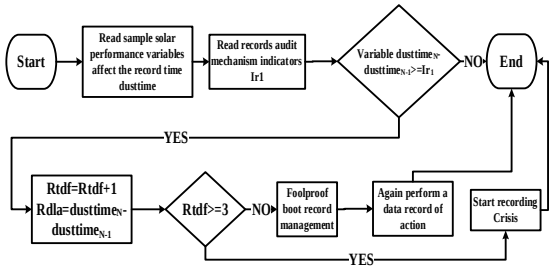


Fig.5.The flowchart of fool-proofing model for records

(2)Crisis Management

As figure 6 shown, the modelof crisis management is established by fuzzy logic. The inputs are Rtdf、Rdla and the output is Rmp.

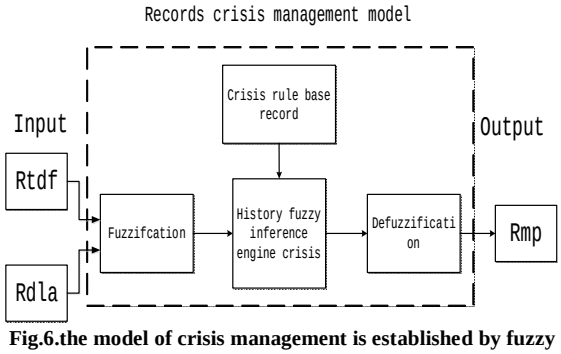


Fig.6.the model of crisis management is established by fuzzy logic

The variable FL model of crisis management is shown as in table 5. It starts if fool-proofingfails in

the mechanism of records, monitoring, assessment, prediction diagnosis, prescription, or scheduling.

Table5: Variables of the model of crisis management

Auditing mechanism	Variable name	Variable Meaning
Record	Rtdf : Record Total Data loss Frequency	Information on the total number of missing records mechanism problem
	Rdla : Recording Data loss amount	Data record mechanism when the number of lost time
	Rmp : Record Maintenance Prescription	Recording mechanism maintenance items and the number of hours
Monitoring	Mtdf : Monitoring Total Data Error Frequency	Data monitoring mechanism is abnormal total number
	Mde : Monitoring Data Error Value	Monitoring data mechanism when the second error value
	Mmp : Monitoring Maintenance Prescription	Maintenance and Monitoring Mechanism project hours
Assessment	Atdf : Assessment Total Data Error Frequency	Data evaluation mechanism is abnormal total number
	Ade : Assessment Data Error Value	Data evaluation mechanism when the second error value
	Amp : Assessment Maintenance Prescription	Evaluation Mechanism of maintenance items and the number of hours
Prediction	Pdtdf : Prediction Total Data Error Frequency	Data prediction mechanism is abnormal total number
	Pdde : Prediction Data Error Value	Data prediction mechanism when the second error value
	Pdmp : Prediction Maintenance Prescription	Forecast mechanism and when the number of maintenance items
Diagnosis	Dtdf : Diagnosis Total Data Error Frequency	Data diagnosis mechanism is abnormal total number
	Dde : Diagnosis Data Error Value	Diagnostic information mechanism when the second error value
	Dmp : Diagnosis Maintenance Prescription	Diagnosis System maintenance items and the number of hours
Prescription	Pstdf : Prescription Total Data Error Frequency	Prescription data mechanism is abnormal total number
	Psde : Prescription Data Error Value	Information prescription mechanism when the second error value
	Psmp : Prescription Maintenance Prescription	Maintenance items and prescription mechanisms hours
Scheduling	Stdf : Scheduling Total Data Error Frequency	Information scheduling mechanism is abnormal total number
	Sdra : Scheduling Data Repeat Amount	Information scheduling mechanism when the number of repetitions
	Smp : Scheduling Maintenance Prescription	Scheduling mechanism and when the number of maintenance items

Table6:The fuzzy rules forcrisis management

Rdla \ Rtdf	S	M	L
S	Rmp_{11}	Rmp_{12}	Rmp_{13}
M	Rmp_{21}	Rmp_{22}	Rmp_{23}
L	Rmp_{31}	Rmp_{32}	Rmp_{33}

By checking table 6, the fuzzy rule is as the followings:

Rule1 : If Rtdf is Small andRdla is Small Then Rmp11

Rule2 : If Rtdf is Small andRdla is Medium Then Rmp21

Rule3 : If Rtdf is Small andRdla is LargeThen Rmp31

Rule4 : If Rtdf is Medium and Rdla is Small Then Rmp12

Rule5 : If Rtdf is Medium and Rdla is Medium Then Rmp22

Rule6 : If Rtdf is Medium and Rdla is Large Then Rmp32

Rule7 : If Rtdf is Large and Rdla is Small Then Rmp13

Rule8 : If Rtdf is Large and Rdla is Medium Then Rmp23

Rule9 : If Rtdf is Large and Rdla is Small Then Rmp33

Table7:parallelism parameter of Crisis Managementof

Functional Mechanisms	Crisis Management Project	parallelism parameter
Record Mechanisms	Cloud data storage capacity has reached the limit, to expand the database space	Rmp_{11}
	Old wire line network, resulting in poor transmission frequency, Ethernet cable replacement	Rmp_{12}
	Check sharing settings whether d ue to IP conflicts result in nosignal transmission	Rmp_{13} Rmp_{21}
	Embedded system cooling system overheating due to poor chip, increase heat sink	Rmp_{22} Rmp_{31}
	Share the link with a new device, confirm that sharing device has failed	Rmp_{23} Rmp_{32}
	New sensors link to confirm whether the sensor has failed	Rmp_{33}

IV. RESULTS AND DISCUSSION

The check mechanism is separated into (1) fool-proofing design module (2) crisis management module. For maintenance of solar energy generating

system, it prevents the fails in the mechanism of records, monitoring, assessment, prediction diagnosis, prescription, or scheduling.

(1)Fool-Proofing Design

Webpage of fool-proofing formaintenance of solar energy generating systemare shown asfigure 7.The preliminary judging is finished by fool-proofing audit indicators.Emoticongraphics will be displayed to present the current mechanism statesof records, monitoring, assessment, prediction diagnosis, prescription, or scheduling. For example, the abnormal state is displayed and the temperature sensor will automatically restart in figure 7.

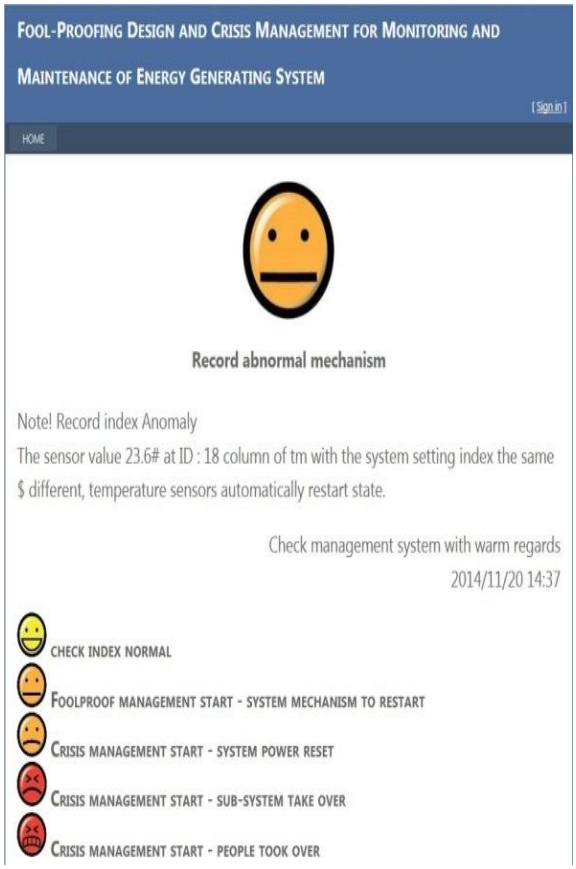


Fig.7.Webpage of fool-proofing formaintenance of solar energy generating system

(2)Crisis Management

If frequency of the abnormal state for the mechanismsof records, monitoring, assessment, prediction diagnosis, prescription, or scheduling is over the standard, the fool-proofing mode transfer to the crisis management mode.Webpage of crisis management for maintenance of solar energy generating system isshown asfigure 8.For example, the field "dusttime" of the table "RXIPVRecord" is over 2 minutes and abnormal frequency of "Rtdf" is over 3 times, and then the crisis management mode is started in figure 8. The preliminary judging is finished by fuzzy logic inference. The reason of abnormal state will be found and the maintenance staff will be informed to take over the system.

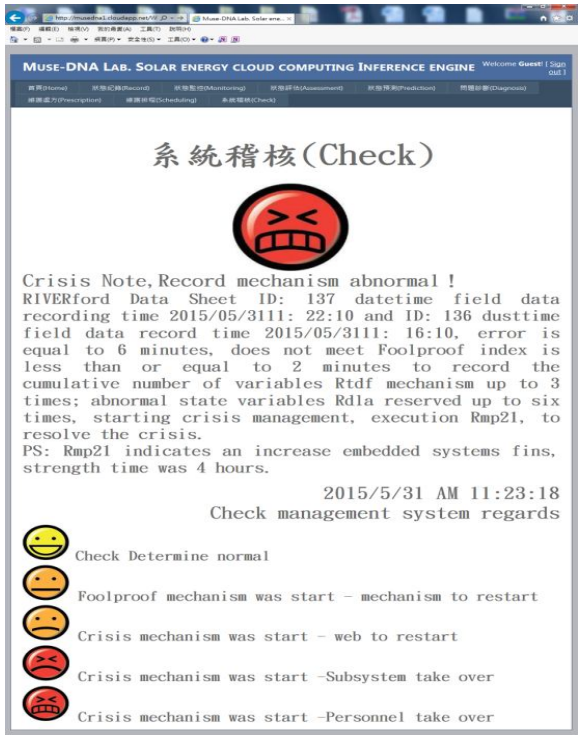


Fig.8.Webpage of crisis management for maintenance of solar energy generating system

CONCLUSIONS

The cloud-dust based system is separated into (1) fool-proofing design module (2) crisis management module. If mistakes prevention is fail, we have to execute the crisis management for stopping harmful results. For avoiding the damages of mechanisms errors, the fool-proofing indexes are set to prevent the failure of the various mechanisms. The states of the various mechanisms are managed by the auto-checked fool-proofing indexes. The crisis management will find the error level and response the solution by fuzzy logic Inference. By the experiments, we can find the advantages of the fool-proofing design and crisis management for monitoring and maintenance of solar energy generating system. And it is rapid and effective to prevent the failure of the various mechanisms of intelligent solar energy generating system.

ACKNOWLEDGMENTS

We would like to thank the Ministry of Science and Technology of the Republic of China (Taiwan) for financial support of this research under contract numbers MOST 104-2221-E-269-012-.

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