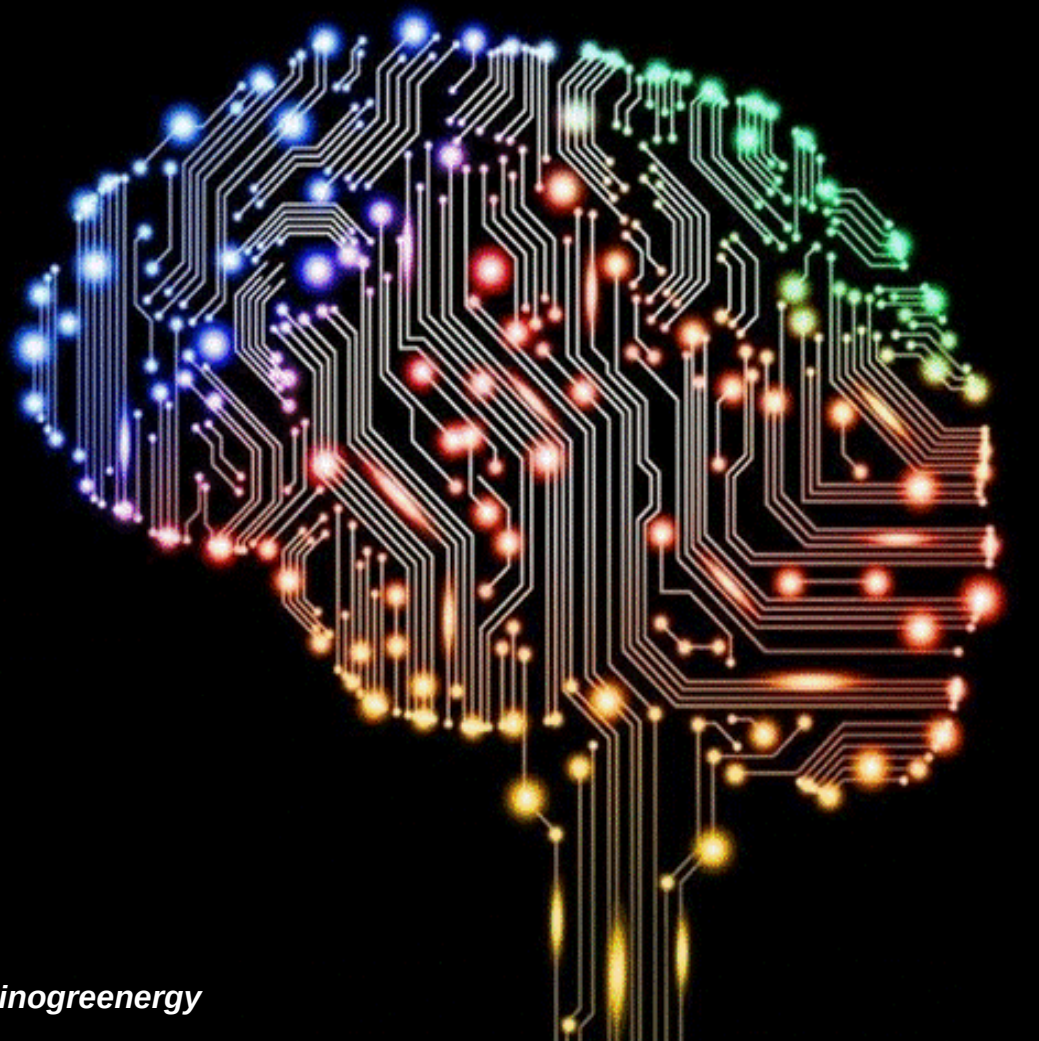
O&M Optimization by AI Practice

The state of the art technology for PV industry



KH CHEN

Chairman of the Sinogreenergy

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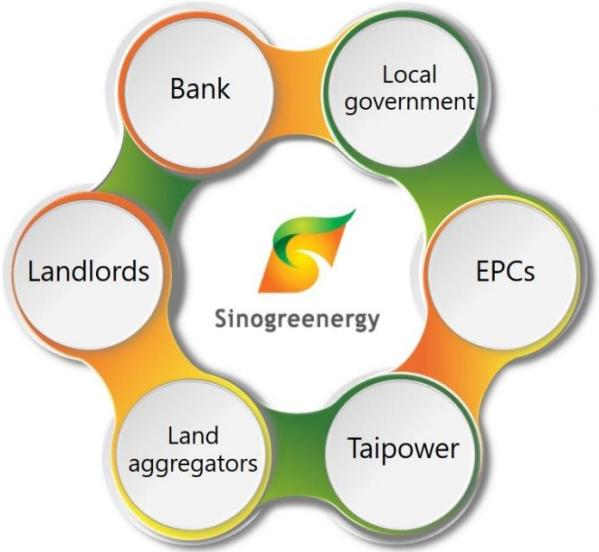
Operating as an Integrated Investment Platform



- Optimize the abundant solar resources in Taiwan and create values to key stakeholders:
  1. Generate clean energy for end-users
  2. Offer stable yields to investors
  3. Add rental income for landlords/ farmers
  4. Improve supply chain of solar PV sector
  5. Provide interest & fee incomes for banks
  6. Create employment opportunities for local communities

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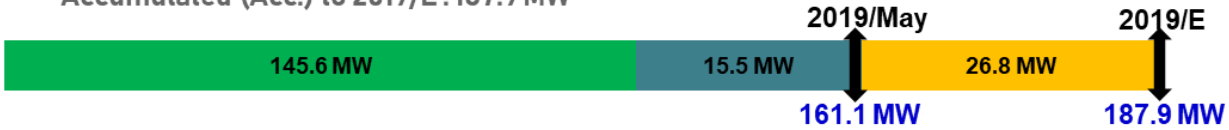
Project Achievements and Pipeline

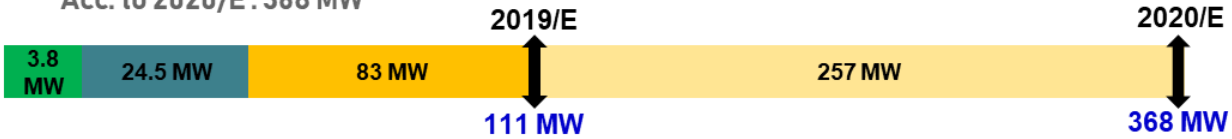
Roof-Top

- On-grid: 145.6 MW
- Under Construction & Developing (in the Process of Tai-Power Approval) : 15.5 MW
- Under Development : 26.8 MW
- Accumulated (Acc.) to 2019/E : 187.9 MW



Ground-Mount

- On-grid: 3.8 MW
- Under Construction : 24.5 MW
- Under Development (2019/E) : 83 MW
- Acc. to 2019/E : 111 MW
  Acc. to 2020/E : 368 MW



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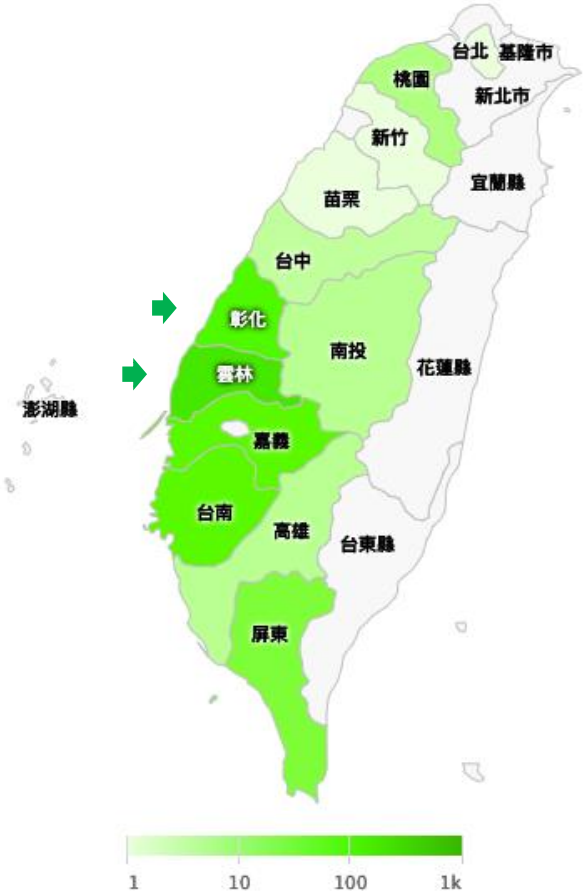
Distribution of Rooftop Projects

Area	Project Site
Yunlin	**187**
Changhua	**105**
Tainan	90
Chiayi	79
Pintung	40
Hualien	25
Taitung	17
Kaohsiung	12
Taichung	11
Taoyuan	11
Hsinchu	9
Nantou	6
Taipei	6
Yilan	6
Miaoli	2
Keelung	1
New Taipei	1
Total	**608**

* Including projects in operation & under construction



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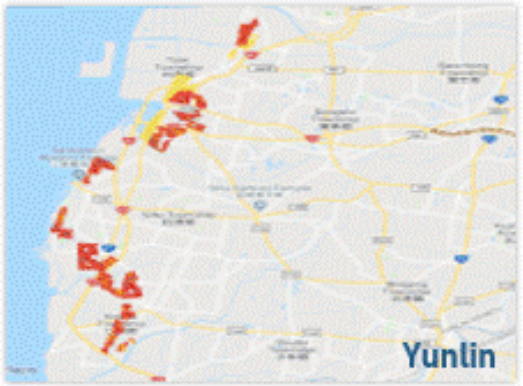
2016~2019 Development of Ground-Mount Projects

Projects	Grid Approval (MW)	BOE Application (MW)
Yunlin Project 1	38.07	30.38 (3.81 COD)
Yunlin Project 2	99.84	36.92
Yunlin Project 3	219.80	74.45 (SubStation Land Ready)
Chiayi Salt Land	20.00	20.00
Changhua Tender	178.16	
Changhua Project	39.98	
Pintung Tender	50.00	50.00
Pintung Project	50 (Application)	50.00 (local Gov. Approval)
Type 3 Ground mount	4.53	4.53
Total	**700.38**	**266.26**



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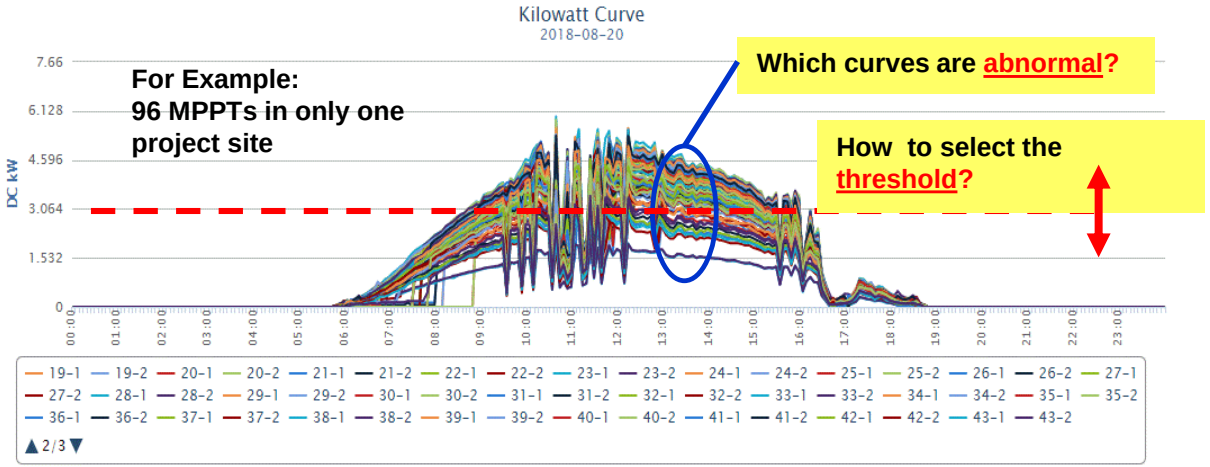
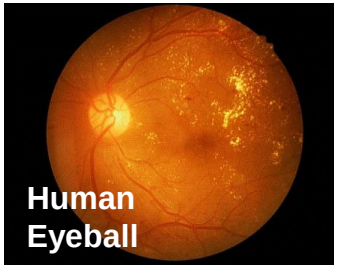
Current O&M Situation

Background & Motivation

Monitoring System





- By manual review (Visual Inspection)?
- How about monitoring 500 projects?
- Automatic judgement? Threshold?
- What should be prepared before dispatching manpower to the field?

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Model

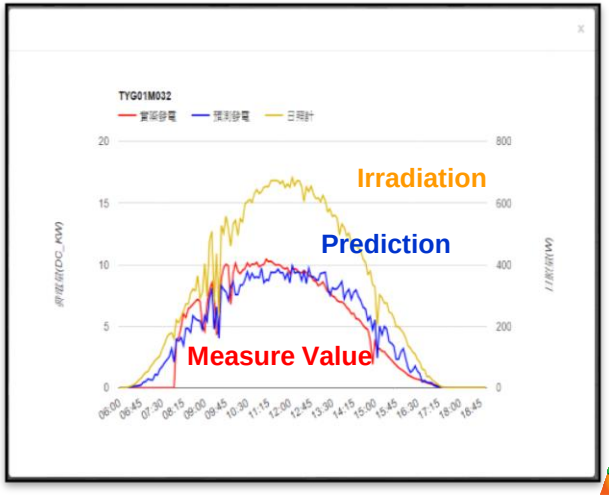
Power Prediction Engine

Power Prediction Engine – Machine Learning

Only 7-day Learning for each Project Sits

Finger-Print is built by each power plant

In-situ analysis in every 5-min



No Specific Parameters to input

- Location / Sea-Level
- Inclination / Azimuth Angle
- PV Module (type/vendor/PAN file)
- Inverter (type/supplier)

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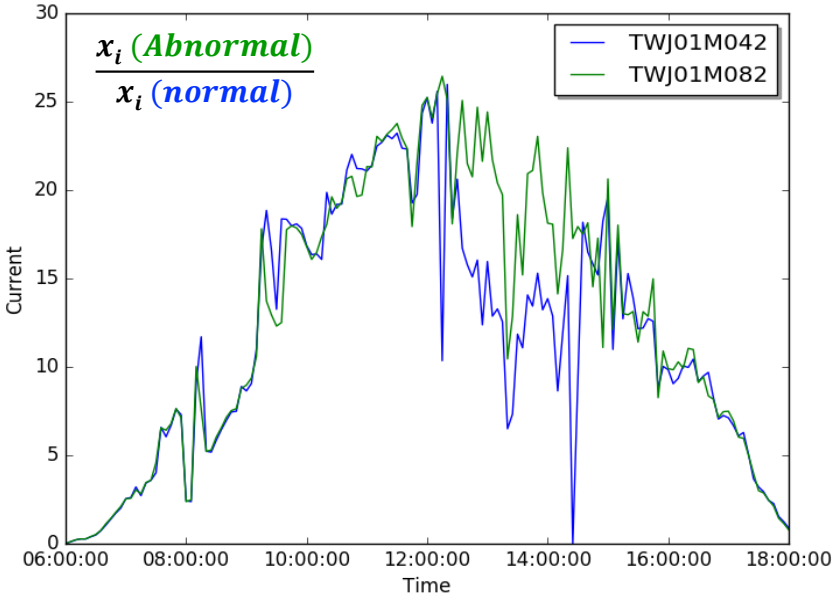
Algorithm

Fault Detection

Fault Detection Algorithm

$$\text{Abnormal Ration} = \sum_{i=1}^{n} \frac{x_i\ (abnormal)}{x_i\ (normal)} / \mathbf{T} \qquad (1)$$

x_i ***(abnormal)***: feature value for low efficient equipment
x_i ***(normal)***: feature value for normal equipment
T: time frame period



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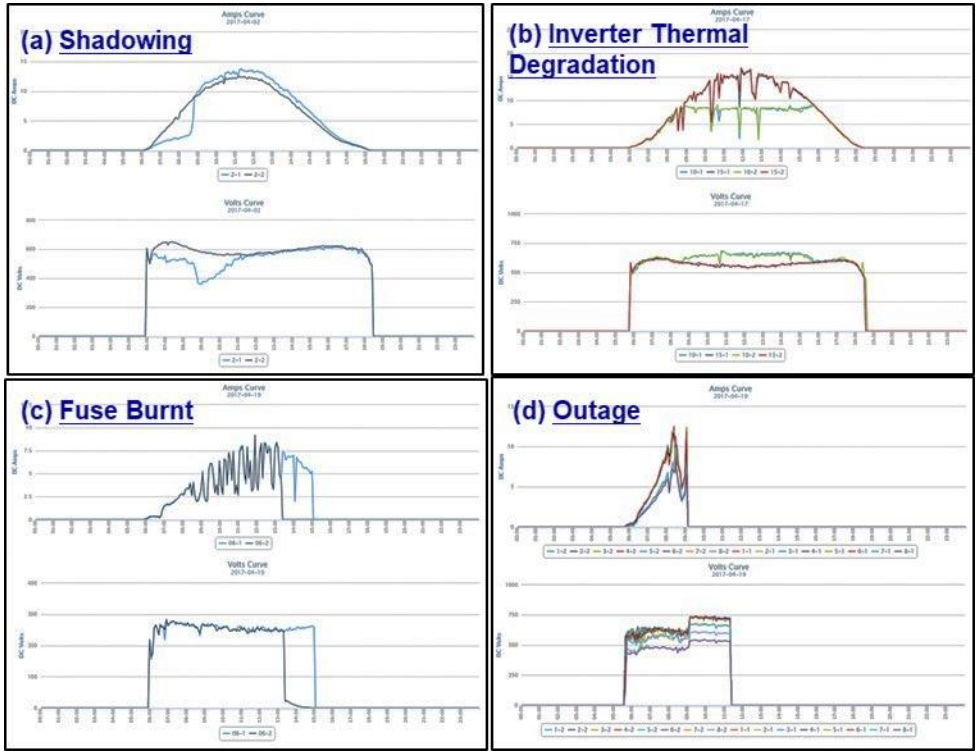
Algorithm

Failure Mode Diagnosis

Knowledge Database



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Verification

Failure Mode Verification

Shadowing

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Verification

Failure Mode Verification

Inverter Thermal Degradation

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Verification

Failure Mode Verification

Fuse Burnt & String Issue

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Verification

Failure Mode Verification

Field Site Outage

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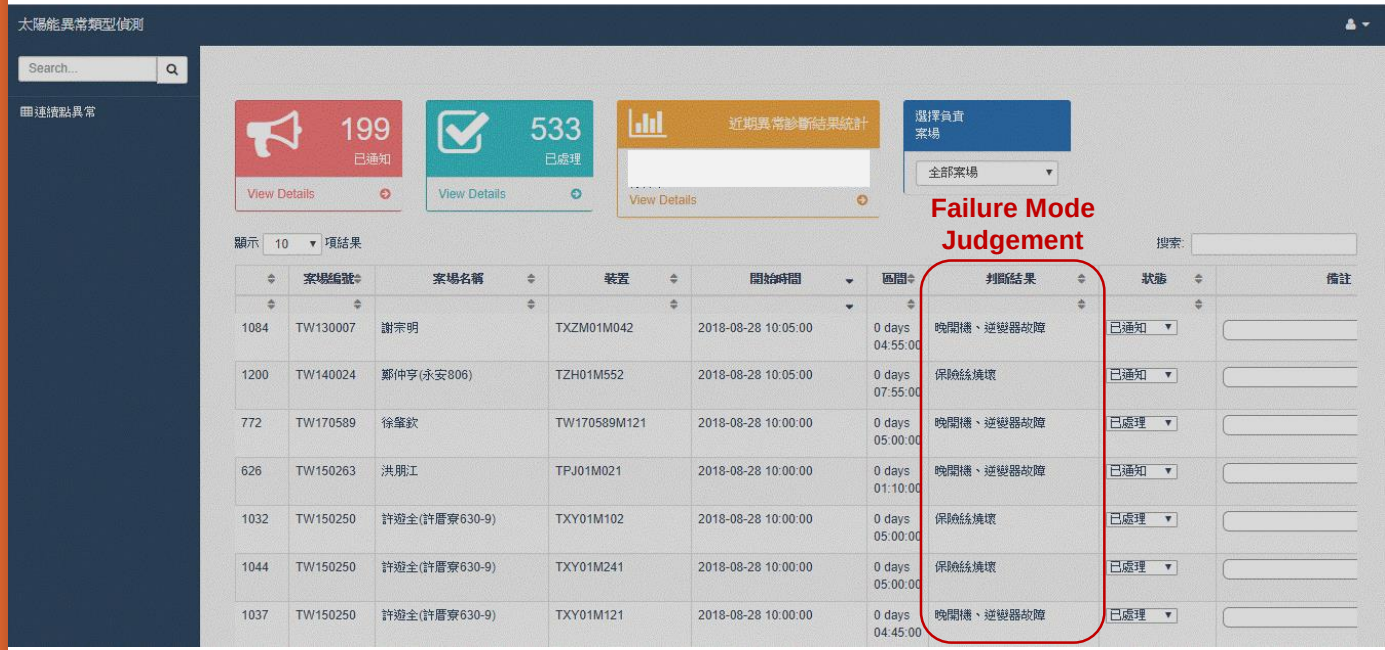
System

Fault Detection & Failure Diagnosis System

Fault Detection & Failure Diagnosis



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Alert

Alert through Mobile & e-mail Message

Alert through IOT Device for User

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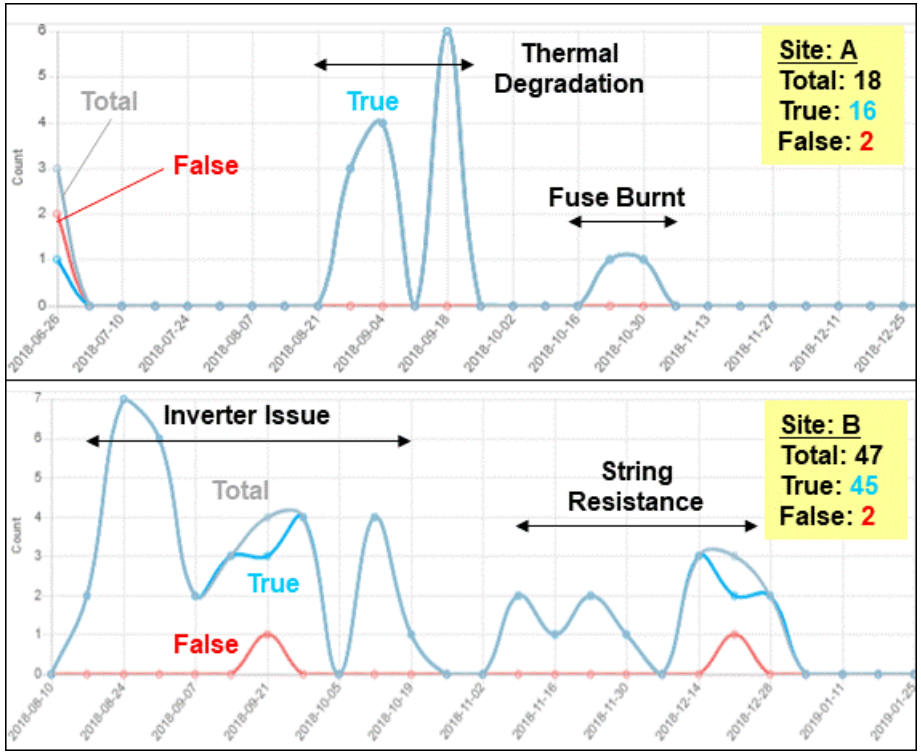
System Development

Learning Curve

System Learning Curve vs. O&M Practice



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System Precision

Fault Detection & Failure Diagnosis

Precision

The precision for fault detection : 99.2%
The precision for failure mode diagnosis : 92.3%

Equipment Faulty Alert	Total	TRUE	FALSE	Precision
	3558	3529	29	99.2%
Failure Mode	**Total**	**TRUE**	**FALSE**	**Precision**
Inverter Issue	1539	1489	50	96.8%
Thermal Degradation (Inverter)	233	218	15	93.6%
Shadowing	766	673	93	87.9%
Fuse Burnt / String Problem	332	318	14	95.8%
Outage for project site / Communication Error	61	58	3	95.1%
Other Faults	583	534	49	91.6%
Unable to Classify	74	23	51	31.1%
Sum	3588	3313	275	92.3%

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System Application

Power Loss & Faulty Capacity Ranking

O&M Priority

Faulty Capacity Statistic (2019-01-27)

Rank	Project No.	Faulty Capacity (kW)	Accumulated Power Loss (kWh)	Number of Faulty Equipment
1	TSYC01	76.8	131.85	4
2	TXZM01	37.1	58.69	2
3	TDE01	22.0	1.32	2
4	TPJO1	12.0	4.97	2
5	TW170584	10.8	3.89	1
6	TW170593	7.8	10.08	3
7	TDL01	6.0	2.87	1
8	TRQ01	5.5	0.32	1

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System Application

Reply Statistic

Manpower & Resource Management

Alert Reply Rate (within a week)

Owner	Project Number	Alert Number	Reply Number	Reply Rate (%)
A	22	14	14	100%
B	20	7	4	57%
C	18	4	4	100%
D	18	15	12	80%
E	18	4	3	75%
F	16	2	2	100%
G	13	55	37	67%
H	10	7	6	86%
I	8	13	10	77%
J	7	2	2	100%

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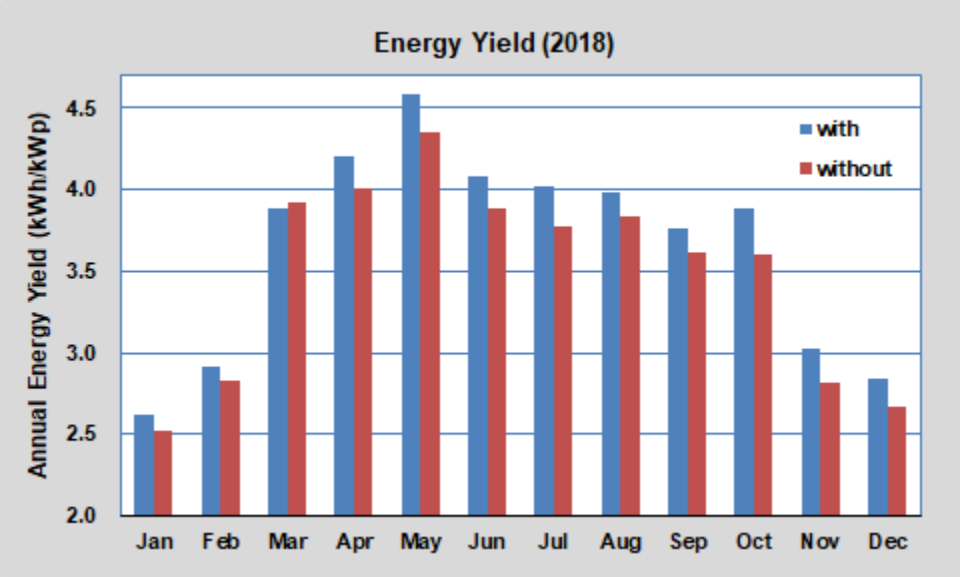
Benefit

Energy Yield Improvement

Energy Yield Improvement

0.16 kWh/kWp (4.7%)

With: 3.65 (120 sites)
Without: 3.49 (120 sites)



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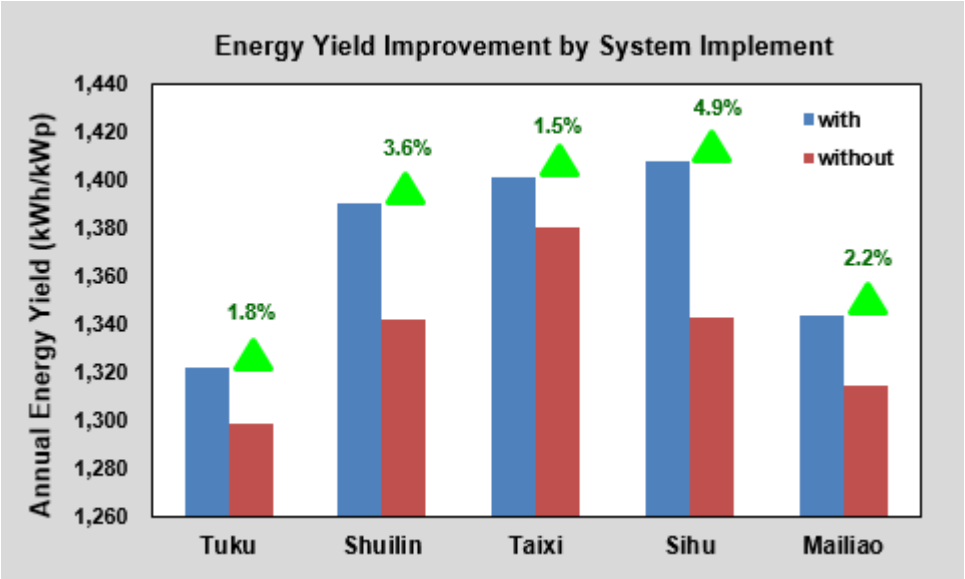
Benefit

Energy Yield Comparison in the same Geographic & Weather Condition

Energy Yield Improvement

1.8% ~ 4.9% (in Yunlin County)



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Achievement

Publication in EU PVSEC 2019

Oral Presentation (5BO.5.3)

23 highest scored abstracts (from **900 worldwide** submitted abstracts) are invited to submit a paper for peer review in the scientific journal **"Progress in Photovoltaics"**.

PROGRESS IN PHOTOVOLTAICS

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