

Condition Monitoring, Asset Management and Security Management for Energy Grid 2.0

Dr Tseng King Jet

Professor of Electrical Engineering

Condition Monitoring, Asset Management and Security Management for Energy Grid 2.0

- Power and energy delivery system for the future urban environment:
 - More distributed generation in terms of geographical localities
 - More diverse in fuel mix
 - More diverse and multi-disciplinary in technologies
 - More complex power flow profile in space and time
- New challenges in meeting the requirements of:
 - Condition monitoring and health prognosis
 - Asset management – tracking in space and time, replacement schedule, compatibility
 - Security management - both physical and cyber



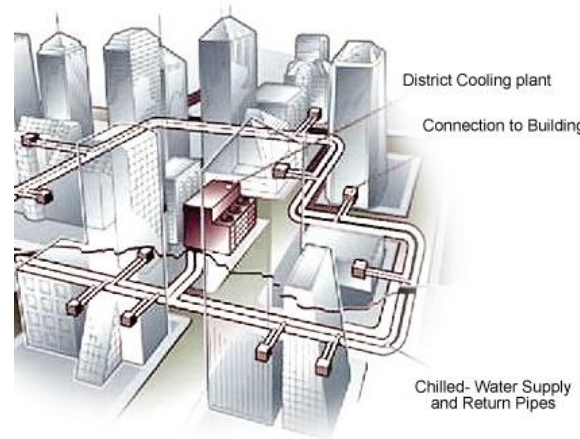
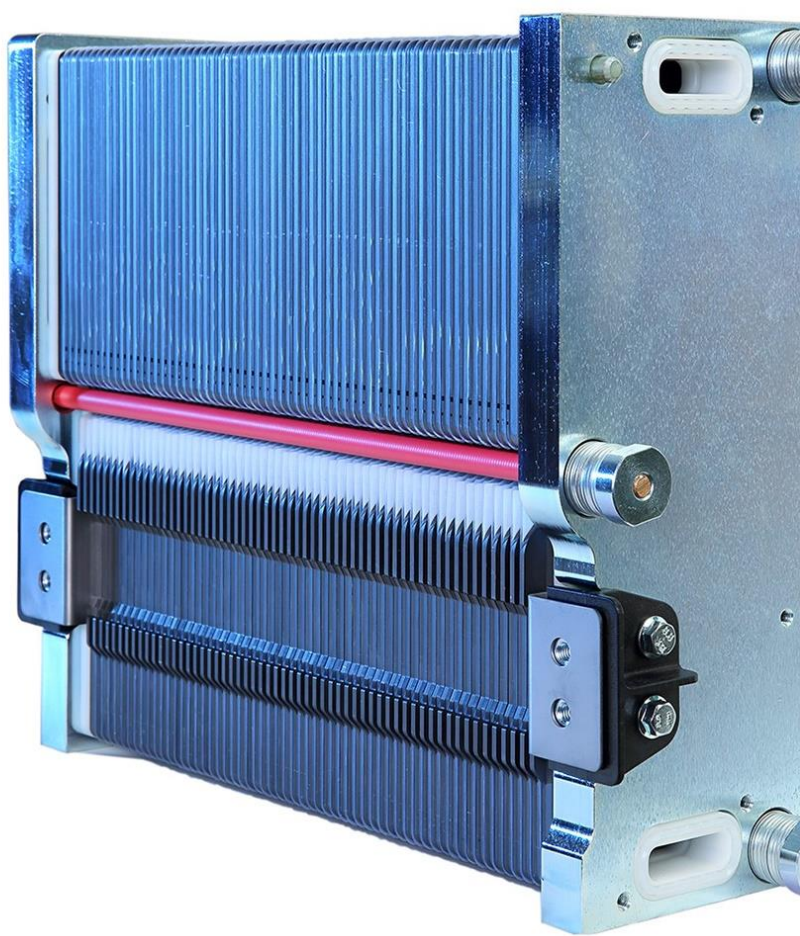
Conventional Power Grid Assets

- Will still be significant in next 50 years
 - Transformers
 - Lines and Cables
 - Central and Distributed Generation Plants
 - Rotating Generators
 - Switchgears
- New technologies for CM, AM, SM will continue to be translated from advances in fundamental research



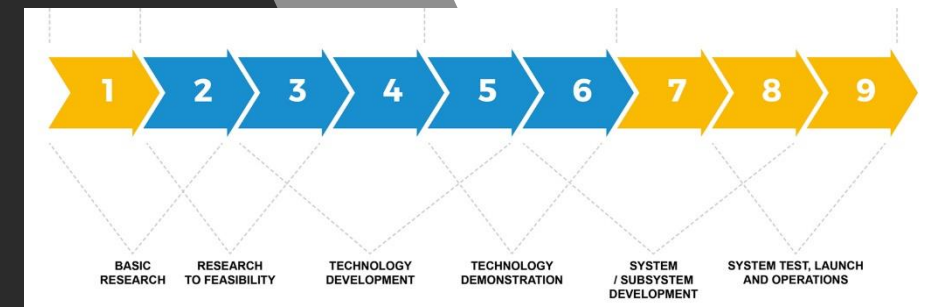
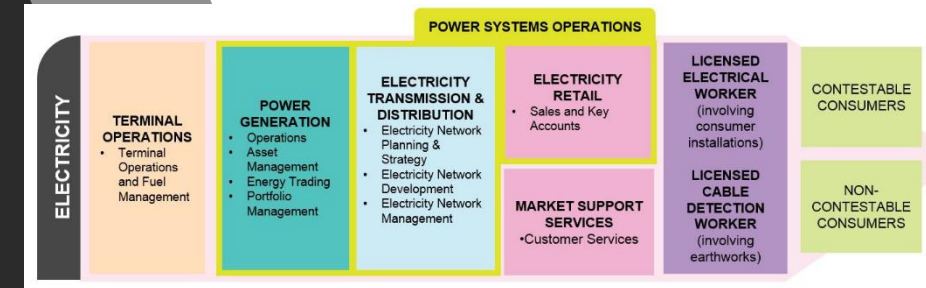
New Types of Assets in Future Energy Grid

- New assets with less understood aging and failure behavior
 - Solar Photovoltaic Panels
 - Energy Storage Systems
 - NG, H2 based Solid State Generation
 - District Cooling Systems
 - Power Electronics based Distribution Network
- Tends to be more digitally connected leading to more potential security issues



Meeting the New Challenges by our IHLs

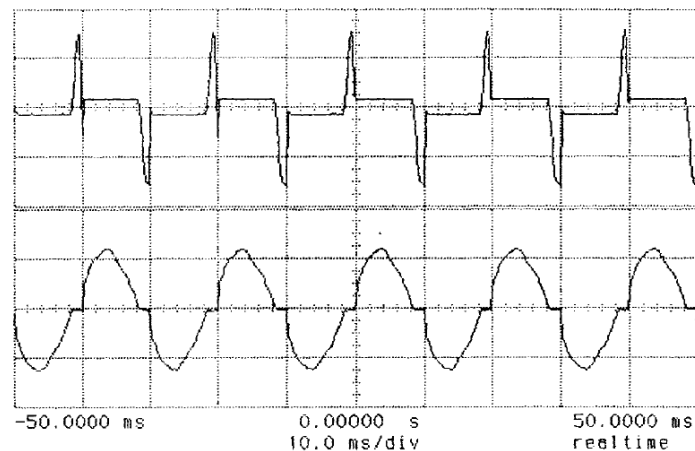
- Capability Development through Applied Education
 - Pre-Employment Training (PET)
 - Diplomas and BEng
 - Continuous Education and Training (CET)
 - Part-time coursework Masters
 - Short courses leading to certificates and professional qualifications
 - Upskilling of professionals
 - Industry Masters and Engineering Doctorates
 - Undertaking industry projects – putting IHLs inside the industries
- Translation of Upstream Research Outcomes
 - To Actual Applications through Applied Research
 - Deep Understanding of Sciences, Mathematics and Humanities
 - Semiconductor Electronics
 - Electro-Statics
 - Electro-Magnetics
 - Electro-Mechanics
 - Electro-Chemicals
 - Thermal and Fluid Dynamics
 - Economics, Finance, Accounting, Environment and Ethics
 - Close Engagement with Engineers and Technicians in the Field



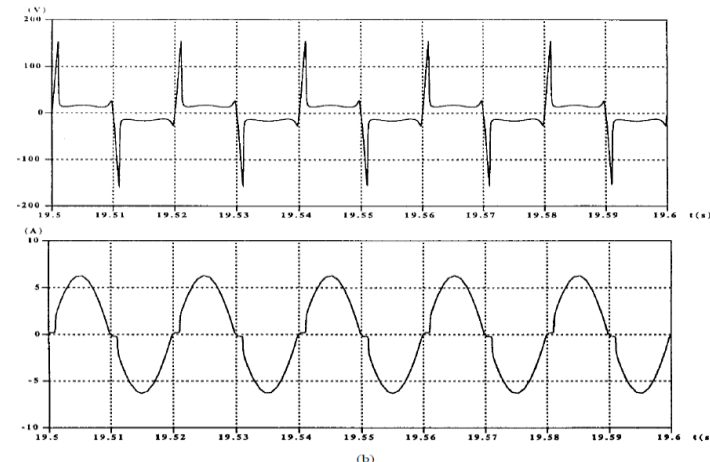
Example of Electric Arc Model Available for Translation

An experimentally verified hybrid Cassie-Mayr electric arc model for power electronics simulations

- An electric arc model that can approximately represent both the static and dynamic characteristics of an arc load controlled by a power electronic circuit.
- The proposed model was developed from the combination and modifications of the classical Cassie and Mayr equations.
- The model equations have been expressed in a form suitable for incorporation into circuit simulators employing the nodal analysis method of equation solving.



(a)

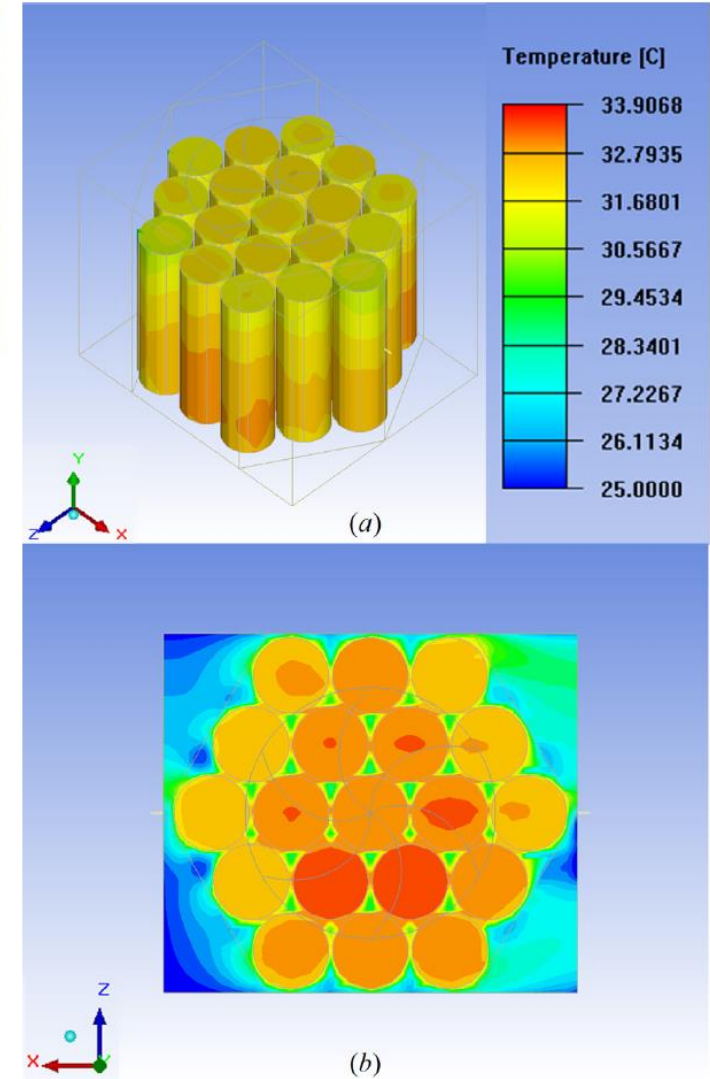
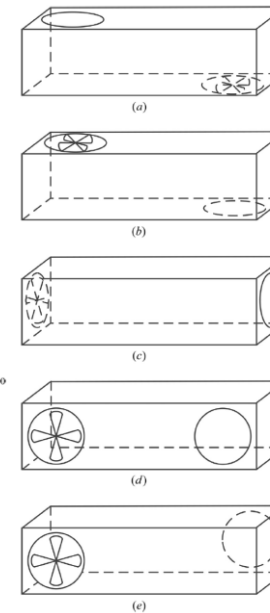
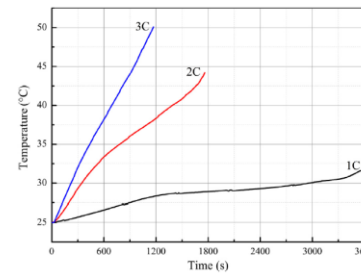


(b)

Example of Thermal Model Available for Translation

Thermal investigation of lithium-ion battery module with different cell arrangement structures and forced air-cooling strategies

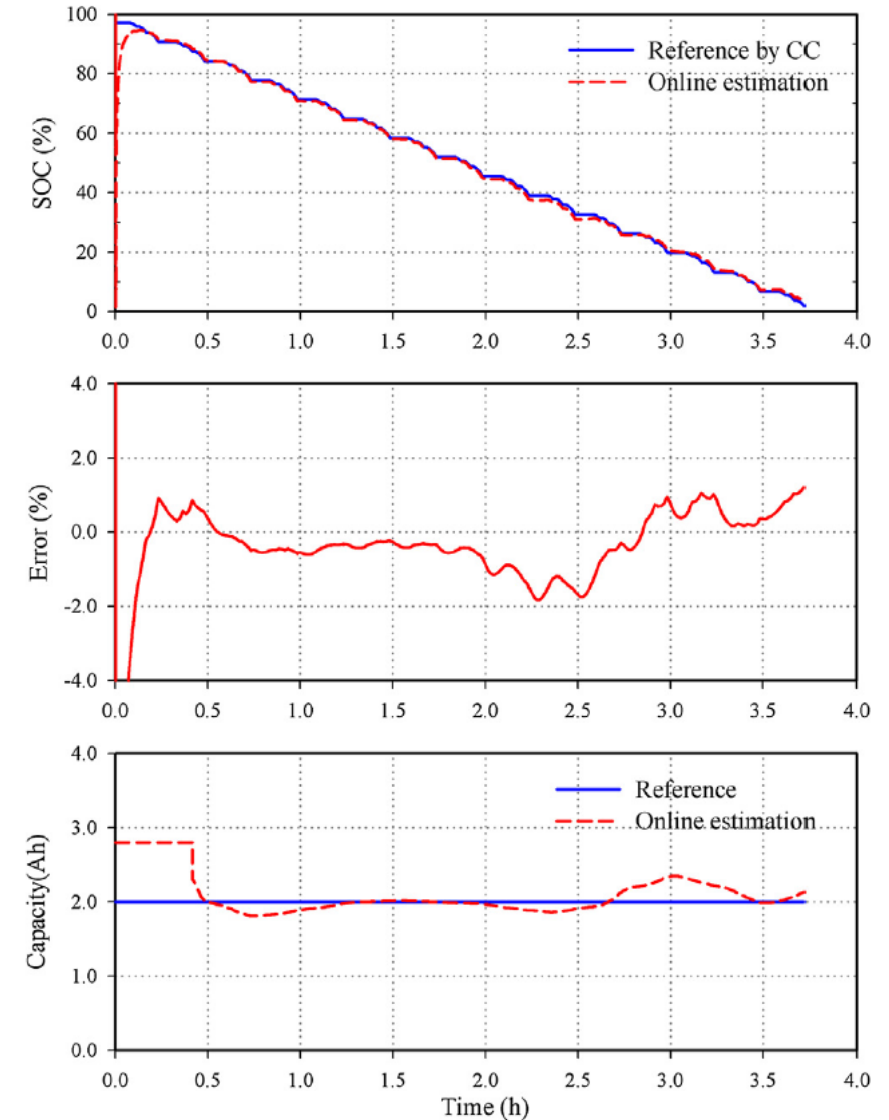
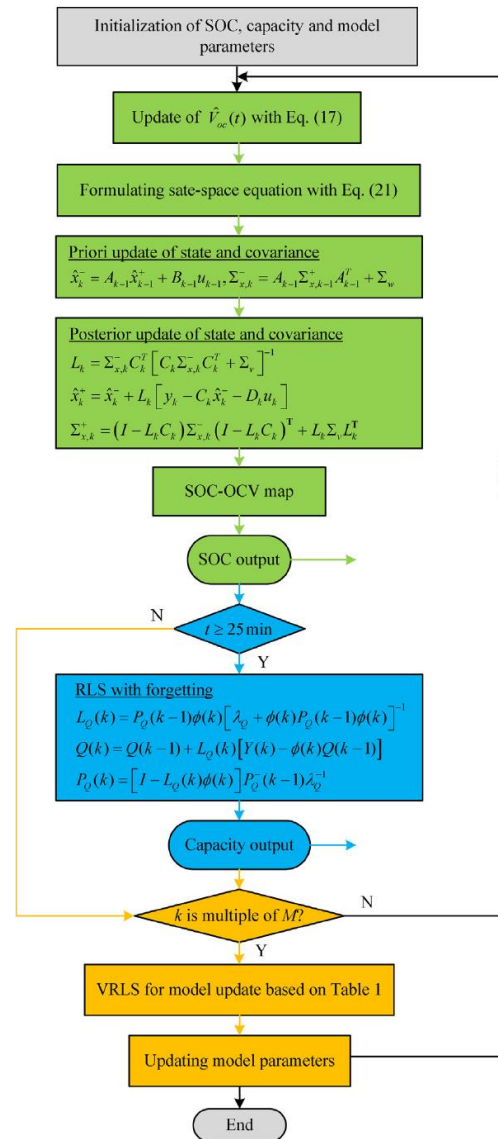
- Three-dimensional CFD model with forced air cooling are developed for battery modules.
- Impact of different air-cooling strategies on module thermal characteristics are investigated.
- Impact of different model structures on module thermal responses are investigated.
- Effect of inter-cell spacing on cell thermal characteristics are also studied.
- The optimal battery module structure and air-cooling strategy is recommended.



Example of Battery Model Available for Translation

A multi-timescale estimator for battery state of charge and capacity dual estimation based on an online identified model

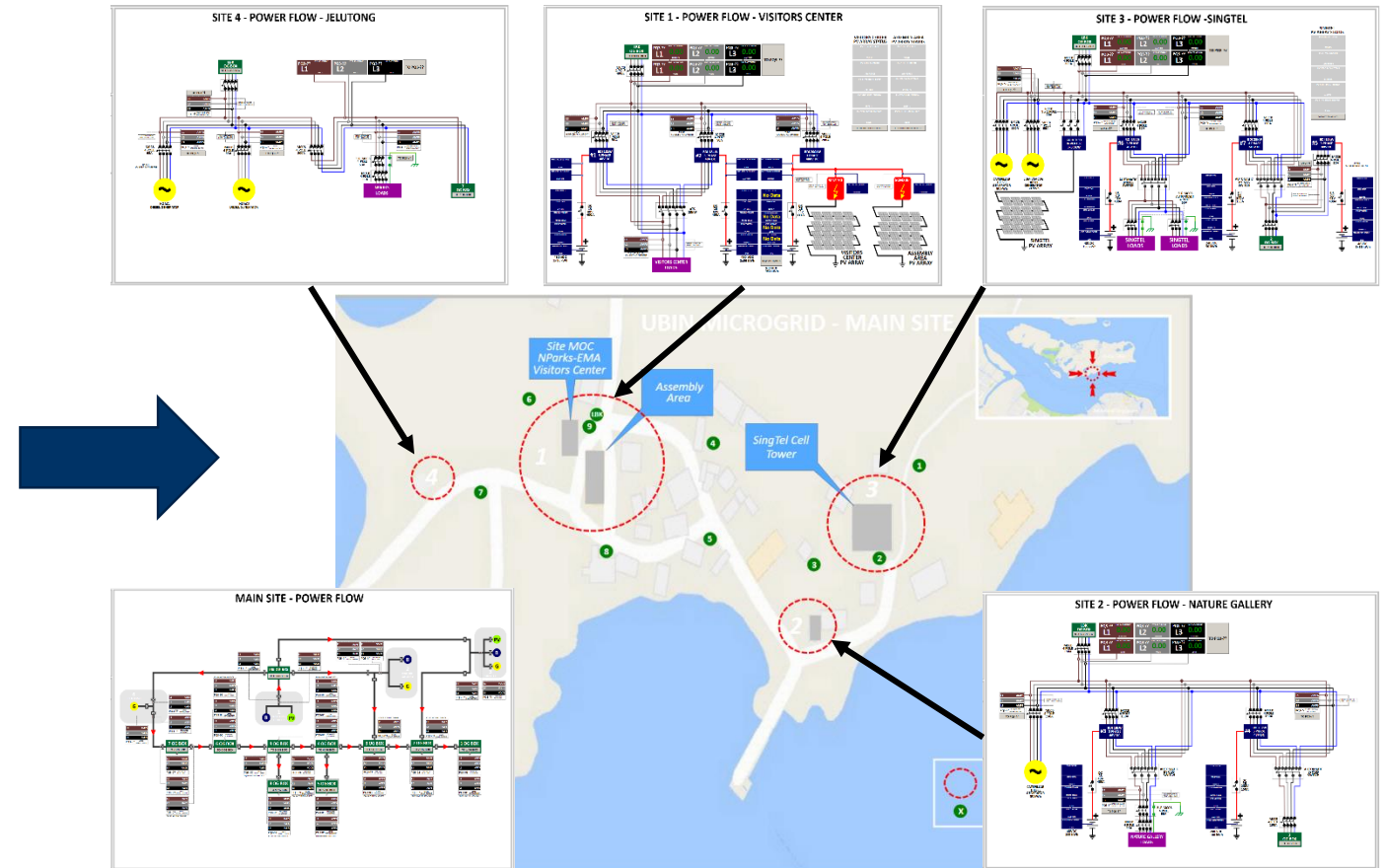
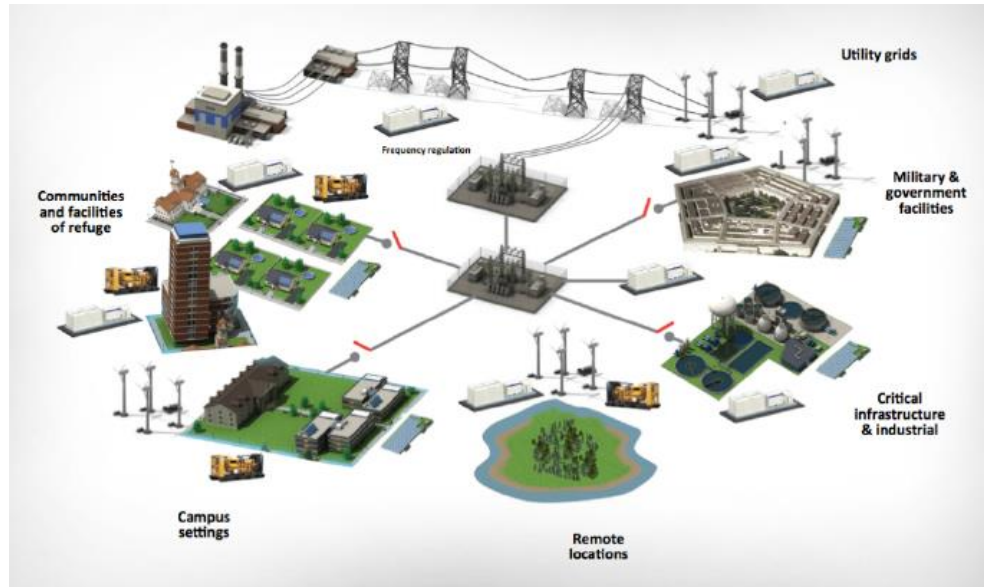
- SOC and capacity are dually estimated with online adapted battery model.
- Model identification and state dual estimate are fully decoupled.
- Multiple timescales are used to improve estimation accuracy and stability.
- The proposed method is verified with lab-scale experiments.
- The proposed method is applicable to different battery chemistries.



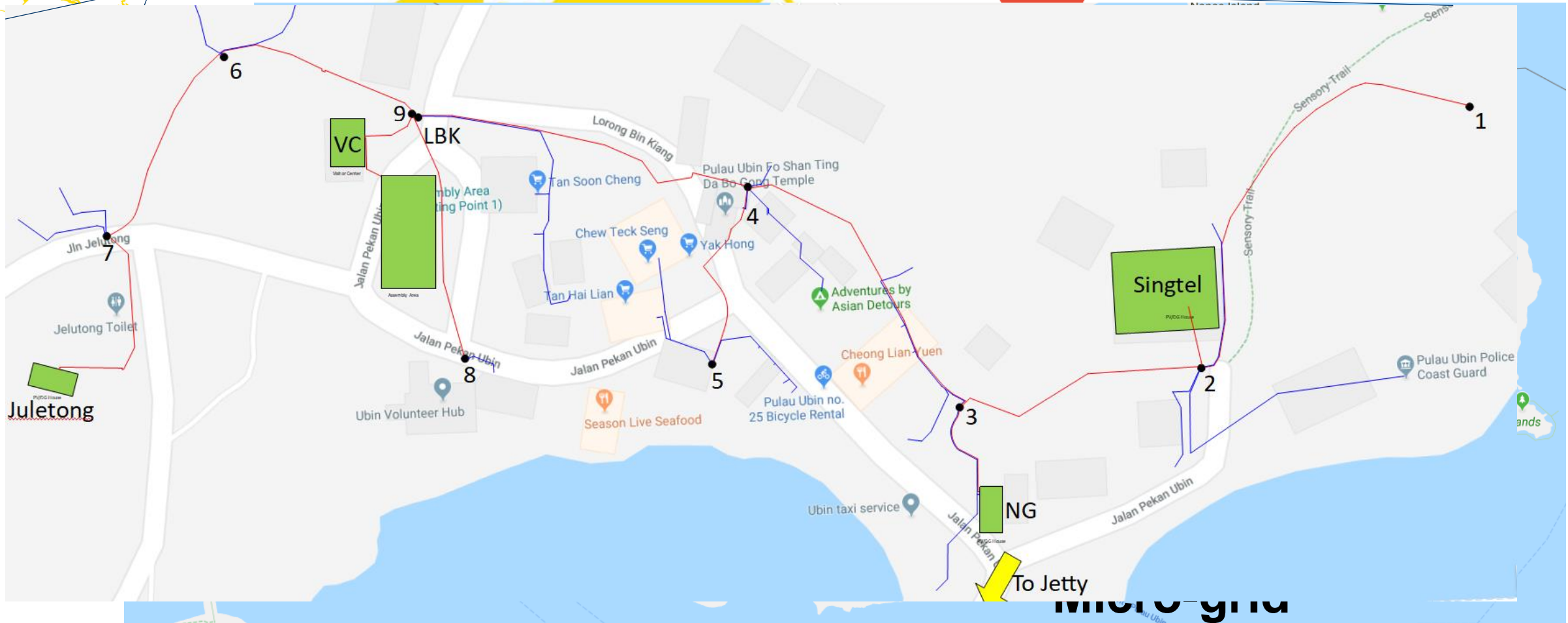
Using Real Power Systems as 'Live' Training Lab

Data Analytics, Visualization, Condition Monitoring

A key teaching/learning paradigm in SIT's
BEng EPE and MEngTech EPE programs



Location of Ubin Micro-grid, Singapore



Users of Ubin Micro-grid



Infrastructure of Ubin Micro-grid

- PV



- BESS



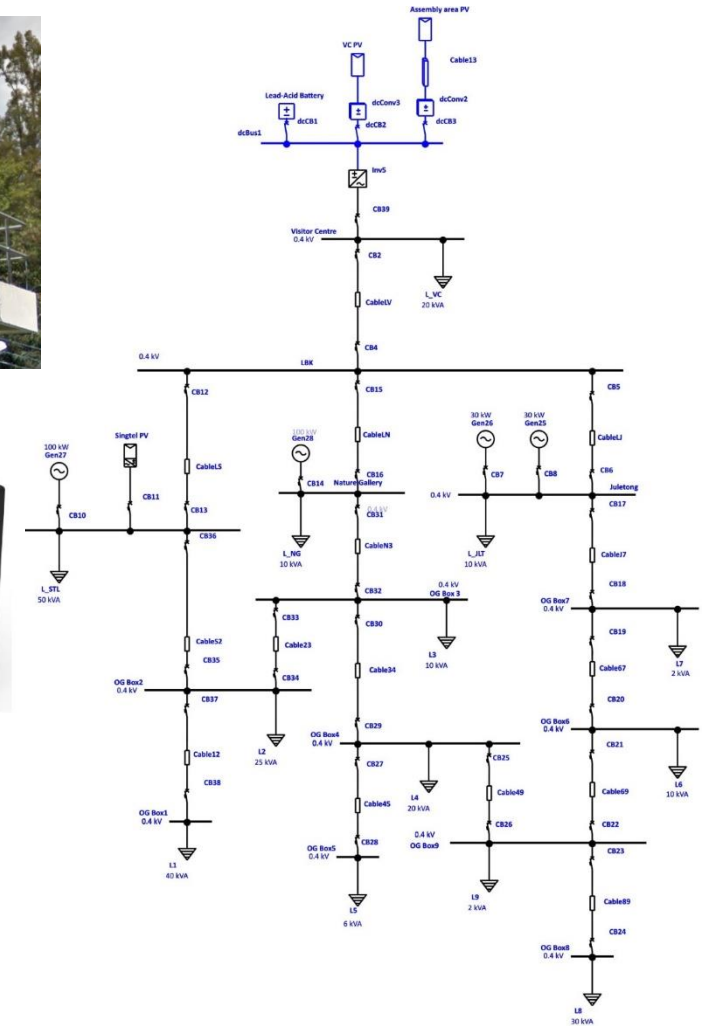
Lead-acid



Hybrid ion



Zinc air



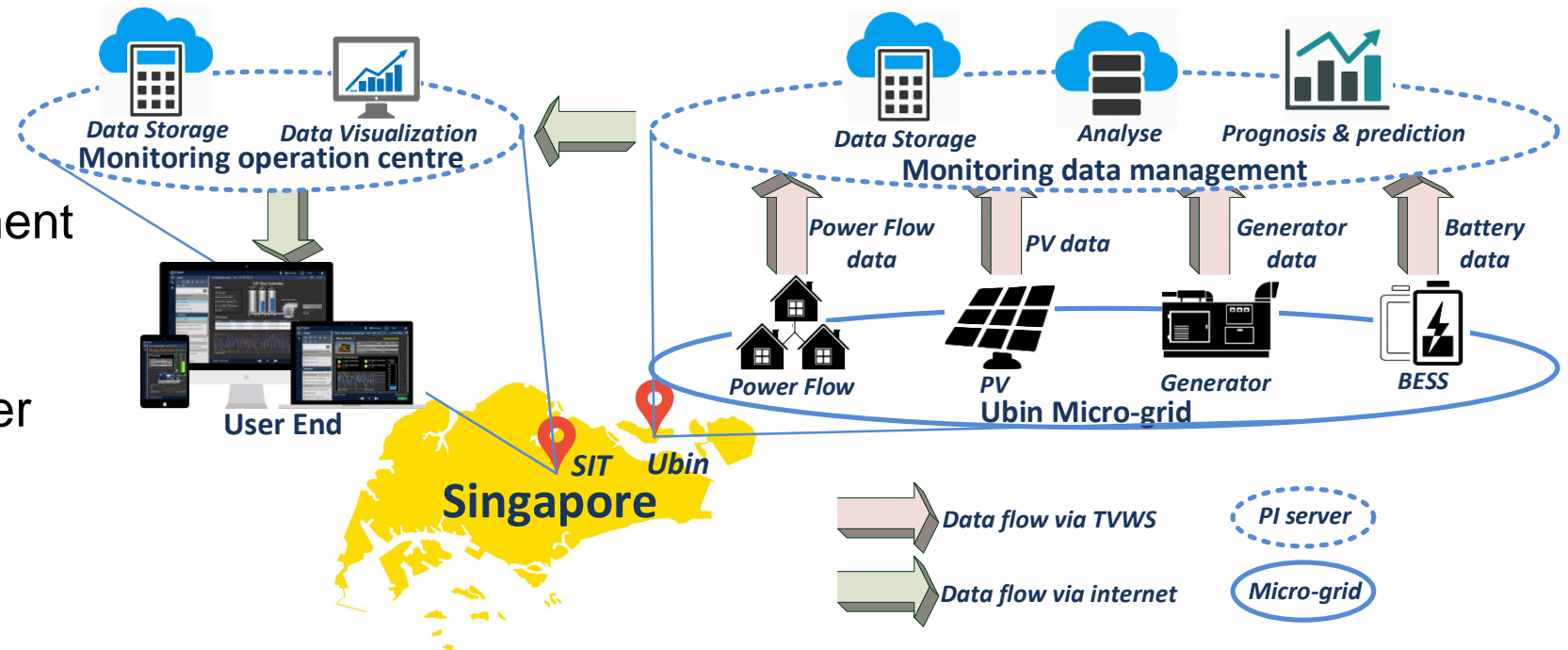
- Hybrid generators



- Single line diagram

Monitoring system of Ubin Micro-grid

- Sensors\meters & data acquisition
- Monitoring data management (local data storage and processing) @ Ubin
- Monitoring operation center (remote data storage and visualization) @ SIT



Monitoring system of Ubin Micro-grid

- Sensors\meters & data acquisition



PV voltage sensor



Air temperature sensor



Irradiance sensor



Power flow & generator monitoring meter: PQube 3



PV temperature sensor



PV current sensor

Data acquisition platform: NI DAQ & LabView

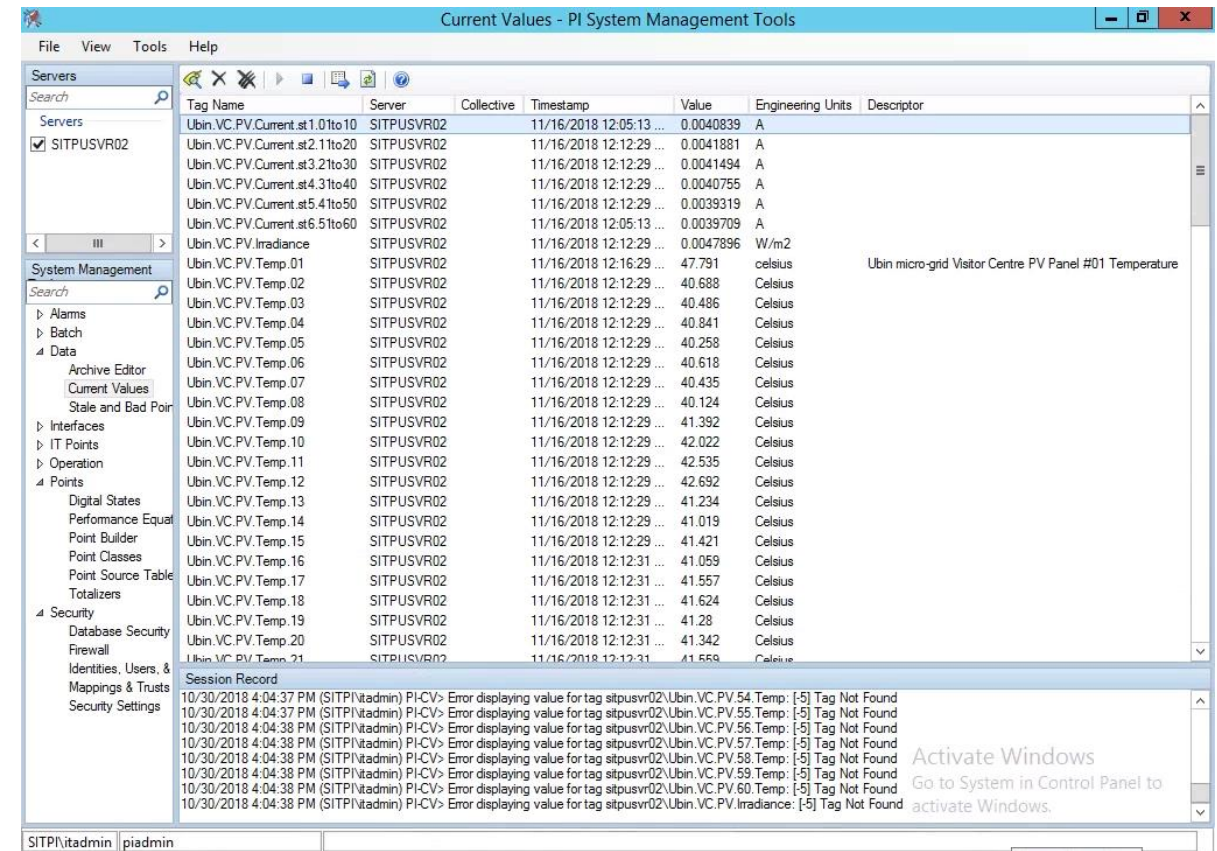


Monitoring system of Ubin Micro-grid

- Monitoring data management (local data storage and processing) @ Ubin



Servers and UPS



Tag Name	Server	Collective	Timestamp	Value	Engineering Units	Descriptor
Ubin.VC.PV.Current.st1.0to10	SITPUSVR02		11/16/2018 12:05:13 ...	0.0040839	A	
Ubin.VC.PV.Current.st2.1to20	SITPUSVR02		11/16/2018 12:12:29 ...	0.0041881	A	
Ubin.VC.PV.Current.st3.2to30	SITPUSVR02		11/16/2018 12:12:29 ...	0.0041494	A	
Ubin.VC.PV.Current.st4.3to40	SITPUSVR02		11/16/2018 12:12:29 ...	0.0040755	A	
Ubin.VC.PV.Current.st5.4to50	SITPUSVR02		11/16/2018 12:12:29 ...	0.0039319	A	
Ubin.VC.PV.Current.st6.5to60	SITPUSVR02		11/16/2018 12:05:13 ...	0.0039709	A	
Ubin.VC.PV.Irradiance	SITPUSVR02		11/16/2018 12:12:29 ...	0.0047896	W/m2	
Ubin.VC.PV.Temp.01	SITPUSVR02		11/16/2018 12:16:29 ...	47.791	celsius	Ubin micro-grid Visitor Centre PV Panel #01 Temperature
Ubin.VC.PV.Temp.02	SITPUSVR02		11/16/2018 12:12:29 ...	40.688	Celsius	
Ubin.VC.PV.Temp.03	SITPUSVR02		11/16/2018 12:12:29 ...	40.486	Celsius	
Ubin.VC.PV.Temp.04	SITPUSVR02		11/16/2018 12:12:29 ...	40.841	Celsius	
Ubin.VC.PV.Temp.05	SITPUSVR02		11/16/2018 12:12:29 ...	40.258	Celsius	
Ubin.VC.PV.Temp.06	SITPUSVR02		11/16/2018 12:12:29 ...	40.618	Celsius	
Ubin.VC.PV.Temp.07	SITPUSVR02		11/16/2018 12:12:29 ...	40.435	Celsius	
Ubin.VC.PV.Temp.08	SITPUSVR02		11/16/2018 12:12:29 ...	40.124	Celsius	
Ubin.VC.PV.Temp.09	SITPUSVR02		11/16/2018 12:12:29 ...	41.392	Celsius	
Ubin.VC.PV.Temp.10	SITPUSVR02		11/16/2018 12:12:29 ...	42.022	Celsius	
Ubin.VC.PV.Temp.11	SITPUSVR02		11/16/2018 12:12:29 ...	42.535	Celsius	
Ubin.VC.PV.Temp.12	SITPUSVR02		11/16/2018 12:12:29 ...	42.692	Celsius	
Ubin.VC.PV.Temp.13	SITPUSVR02		11/16/2018 12:12:29 ...	41.234	Celsius	
Ubin.VC.PV.Temp.14	SITPUSVR02		11/16/2018 12:12:29 ...	41.019	Celsius	
Ubin.VC.PV.Temp.15	SITPUSVR02		11/16/2018 12:12:29 ...	41.421	Celsius	
Ubin.VC.PV.Temp.16	SITPUSVR02		11/16/2018 12:12:31 ...	41.059	Celsius	
Ubin.VC.PV.Temp.17	SITPUSVR02		11/16/2018 12:12:31 ...	41.557	Celsius	
Ubin.VC.PV.Temp.18	SITPUSVR02		11/16/2018 12:12:31 ...	41.624	Celsius	
Ubin.VC.PV.Temp.19	SITPUSVR02		11/16/2018 12:12:31 ...	41.28	Celsius	
Ubin.VC.PV.Temp.20	SITPUSVR02		11/16/2018 12:12:31 ...	41.342	Celsius	
Ubin.VC.PV.Temp.21	SITPUSVR02		11/16/2018 12:12:31 ...	41.559	Celsius	

Session Record

10/30/2018 4:04:37 PM (SITPI\itadmin) PI-CV> Error displaying value for tag sitpusvr02\Ubin.VC.PV.54.Temp: [-5] Tag Not Found

10/30/2018 4:04:37 PM (SITPI\itadmin) PI-CV> Error displaying value for tag sitpusvr02\Ubin.VC.PV.55.Temp: [-5] Tag Not Found

10/30/2018 4:04:38 PM (SITPI\itadmin) PI-CV> Error displaying value for tag sitpusvr02\Ubin.VC.PV.56.Temp: [-5] Tag Not Found

10/30/2018 4:04:38 PM (SITPI\itadmin) PI-CV> Error displaying value for tag sitpusvr02\Ubin.VC.PV.57.Temp: [-5] Tag Not Found

10/30/2018 4:04:38 PM (SITPI\itadmin) PI-CV> Error displaying value for tag sitpusvr02\Ubin.VC.PV.58.Temp: [-5] Tag Not Found

10/30/2018 4:04:38 PM (SITPI\itadmin) PI-CV> Error displaying value for tag sitpusvr02\Ubin.VC.PV.59.Temp: [-5] Tag Not Found

10/30/2018 4:04:38 PM (SITPI\itadmin) PI-CV> Error displaying value for tag sitpusvr02\Ubin.VC.PV.60.Temp: [-5] Tag Not Found

10/30/2018 4:04:38 PM (SITPI\itadmin) PI-CV> Error displaying value for tag sitpusvr02\Ubin.VC.PV.Irradiance: [-5] Tag Not Found

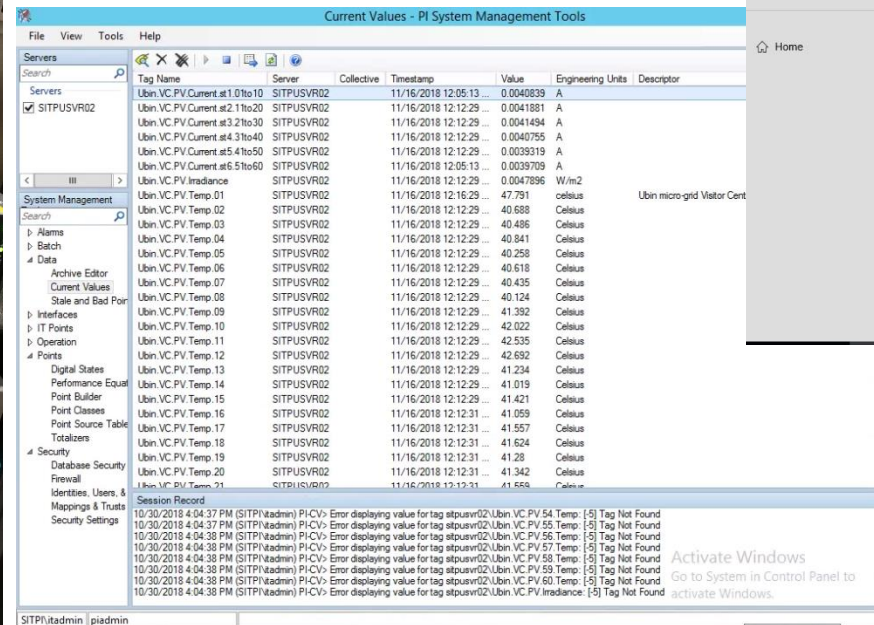
PI system based data storage and processing

Monitoring system of Ubin Micro-grid

- Monitoring operation center (remote data storage and visualization) @ SIT

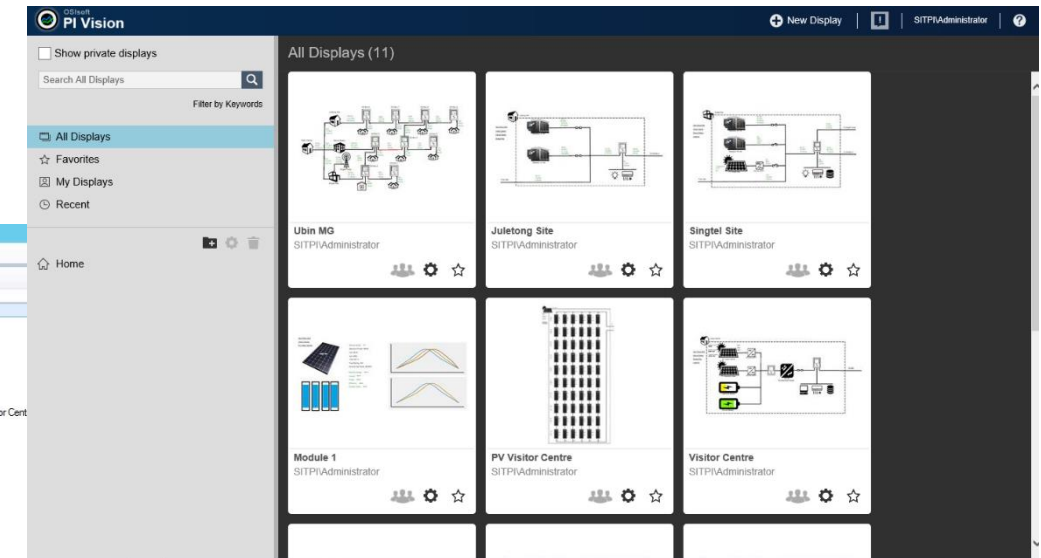


Servers and UPS



Tag Name	Server	Collective	Timestamp	Value	Engineering Units	Descriptor
Ubin.VC.PV.Current.a1.0to10	SITPUSVR02		11/16/2018 12:05:13	0.0040839	A	
Ubin.VC.PV.Current.a2.1to20	SITPUSVR02		11/16/2018 12:12:29	0.0041881	A	
Ubin.VC.PV.Current.a3.20to30	SITPUSVR02		11/16/2018 12:12:29	0.0041494	A	
Ubin.VC.PV.Current.a4.3to40	SITPUSVR02		11/16/2018 12:12:29	0.0040755	A	
Ubin.VC.PV.Current.a5.5to50	SITPUSVR02		11/16/2018 12:12:29	0.0039319	A	
Ubin.VC.PV.Current.a6.5to60	SITPUSVR02		11/16/2018 12:05:13	0.0039709	A	
Ubin.VC.PV.Irradiance	SITPUSVR02		11/16/2018 12:12:29	0.0047896	W/m2	Ubin micro-grid Visitor Centre
Ubin.VC.PV.Temp.01	SITPUSVR02		11/16/2018 12:16:29	47.791	Celsius	
Ubin.VC.PV.Temp.02	SITPUSVR02		11/16/2018 12:12:29	40.688	Celsius	
Ubin.VC.PV.Temp.03	SITPUSVR02		11/16/2018 12:12:29	40.486	Celsius	
Ubin.VC.PV.Temp.04	SITPUSVR02		11/16/2018 12:12:29	40.841	Celsius	
Ubin.VC.PV.Temp.05	SITPUSVR02		11/16/2018 12:12:29	40.258	Celsius	
Ubin.VC.PV.Temp.06	SITPUSVR02		11/16/2018 12:12:29	40.618	Celsius	
Ubin.VC.PV.Temp.07	SITPUSVR02		11/16/2018 12:12:29	40.435	Celsius	
Ubin.VC.PV.Temp.08	SITPUSVR02		11/16/2018 12:12:29	40.124	Celsius	
Ubin.VC.PV.Temp.09	SITPUSVR02		11/16/2018 12:12:29	41.392	Celsius	
Ubin.VC.PV.Temp.10	SITPUSVR02		11/16/2018 12:12:29	42.022	Celsius	
Ubin.VC.PV.Temp.11	SITPUSVR02		11/16/2018 12:12:29	42.535	Celsius	
Ubin.VC.PV.Temp.12	SITPUSVR02		11/16/2018 12:12:29	42.692	Celsius	
Ubin.VC.PV.Temp.13	SITPUSVR02		11/16/2018 12:12:29	41.234	Celsius	
Ubin.VC.PV.Temp.14	SITPUSVR02		11/16/2018 12:12:29	41.019	Celsius	
Ubin.VC.PV.Temp.15	SITPUSVR02		11/16/2018 12:12:29	41.421	Celsius	
Ubin.VC.PV.Temp.16	SITPUSVR02		11/16/2018 12:12:31	41.059	Celsius	
Ubin.VC.PV.Temp.17	SITPUSVR02		11/16/2018 12:12:31	41.557	Celsius	
Ubin.VC.PV.Temp.18	SITPUSVR02		11/16/2018 12:12:31	41.624	Celsius	
Ubin.VC.PV.Temp.19	SITPUSVR02		11/16/2018 12:12:31	41.28	Celsius	
Ubin.VC.PV.Temp.20	SITPUSVR02		11/16/2018 12:12:31	41.342	Celsius	
Ubin.VC.PV.Temp.21	SITPUSVR02		11/16/2018 12:12:31	41.658	Celsius	

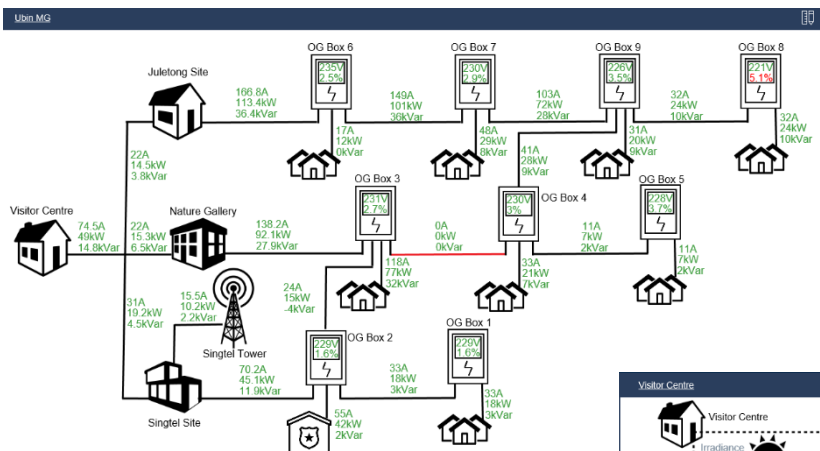
PI system based data storage



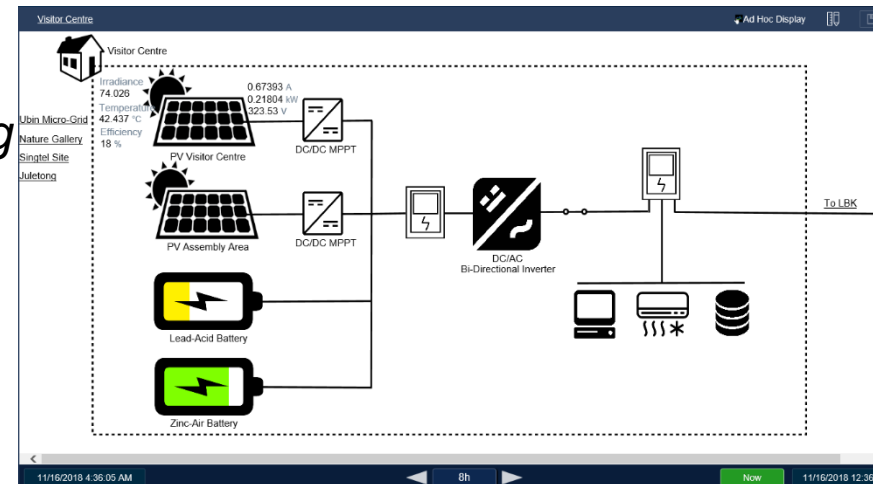
PI system based visualization design (user interface)

Monitoring system of Ubin Micro-grid

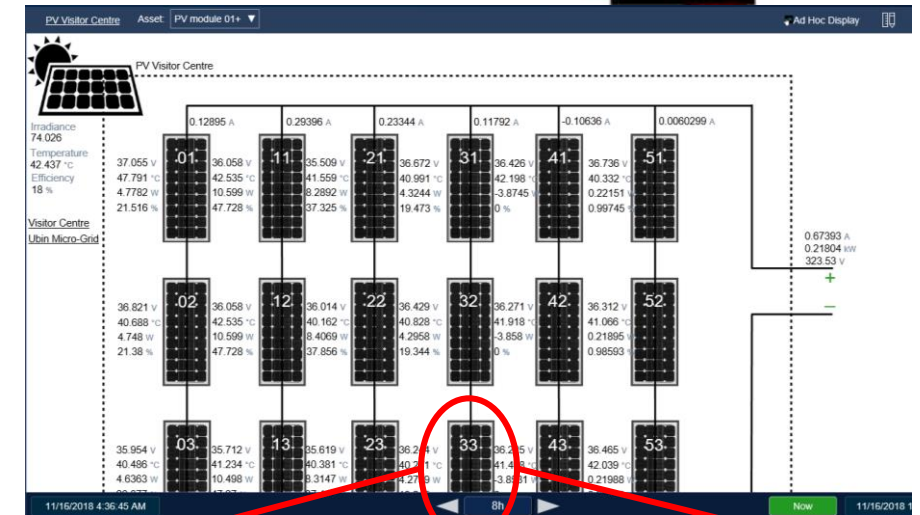
- *visualization design (user interface)*



Grid level monitoring

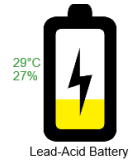


Site level monitoring

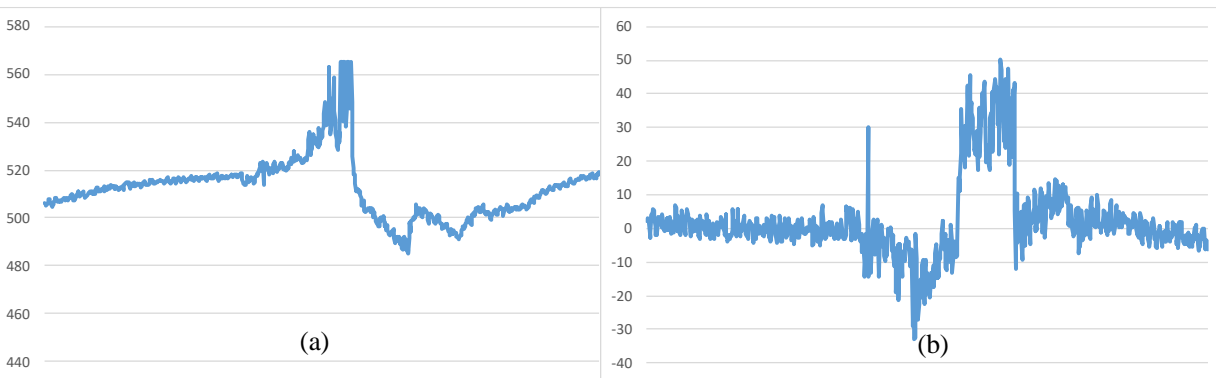
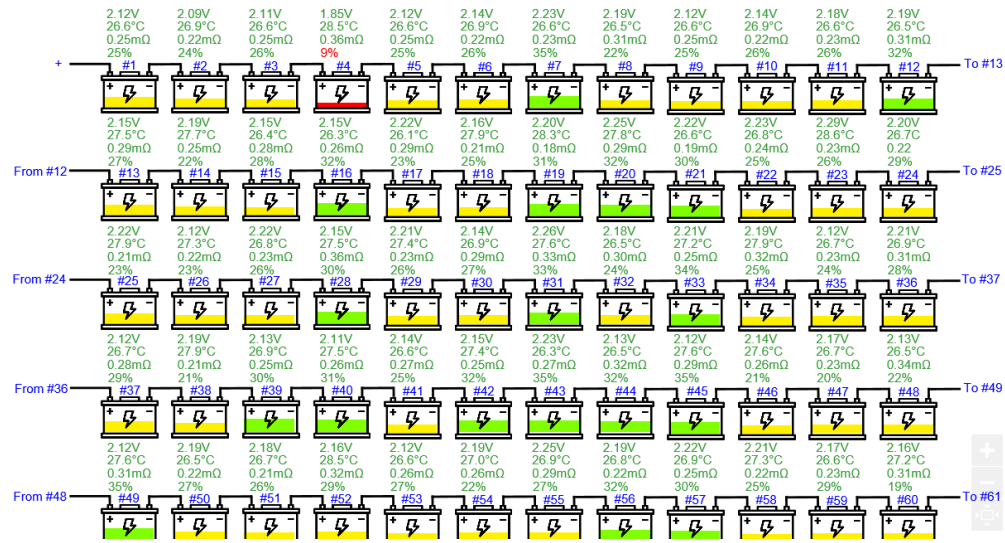


Module/cell level monitoring

Sample monitoring data



Lead-Acid Battery
Visitor Centre
Ubin Micro-Grid

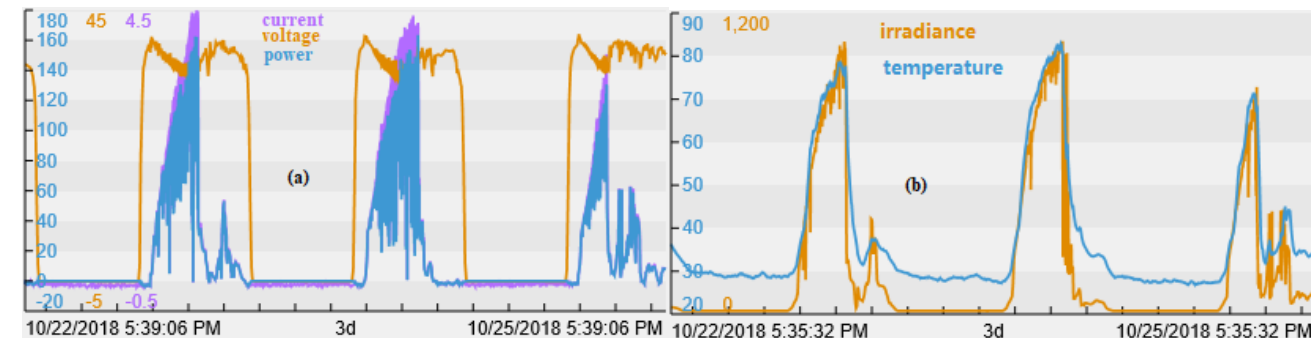
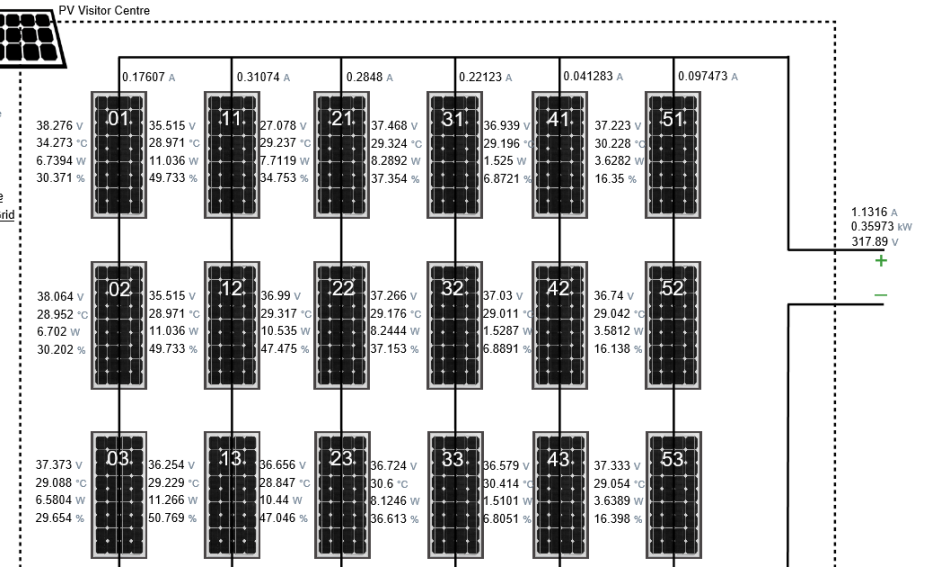


24 hour historical data for (a) voltage and (b) current waveform of battery bank

Battery monitoring and sample data



PV Visitor Centre
Irradiance 73.969
Temperature 30.537 °C
Efficiency 29.72 %
Visitor Centre
Ubin Micro-Grid



3 day historical data for (a) current, voltage and power (b) irradiance and temperature

PV monitoring and sample data

References

Thermal investigation of lithium-ion battery module with different cell arrangement structures and forced air-cooling strategies

T Wang, KJ Tseng, J Zhao, Z Wei
Applied energy 134, 229-238

An experimentally verified hybrid Cassie-Mayr electric arc model for power electronics simulations

KJ Tseng, Y Wang, DM Vilathgamuwa
IEEE Transactions on Power Electronics 12 (3), 429-436

A multi-timescale estimator for battery state of charge and capacity dual estimation based on an online identified model

Z Wei, J Zhao, D Ji, KJ Tseng
Applied energy 204, 1264-1274

A Non-Invasive On-line Condition Monitoring and Health Prognosis System for a Remote Islanded Micro-Grid

W Feng, C Shuyu, LZ Kiat, C Xuebing, KJ Tseng
2018 International Conference on Smart Grid (icSmartGrid), 46-51

Impulsive noise reduction for transient Earth voltage-based partial discharge using Wavelet-entropy

G Luo, D Zhang, KJ Tseng, J He
IET Science, Measurement & Technology 10 (1), 69-76