Energy Management System and Resilient Control of Distribution Feeder with Microgrid Technology

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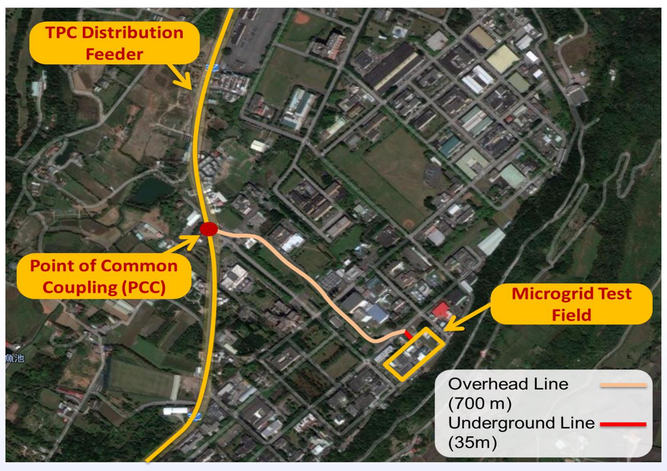
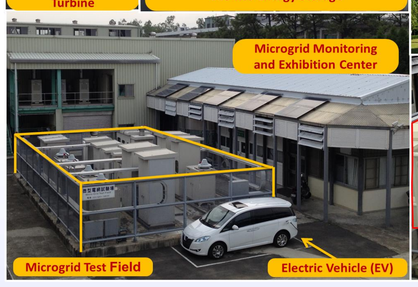
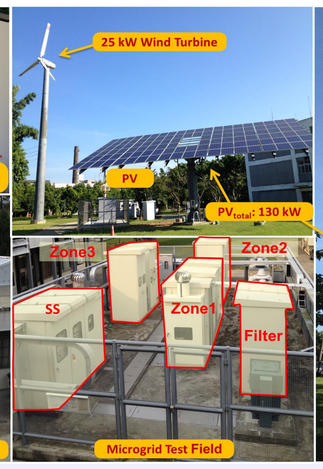
Objective

As a result of conventional fossil fuel shortage and global warming, the research trend of world goes into raising the usage of renewable energy, stabilizing regional balance of energy supply and demand, and promoting smart grid technology. However, due to the intermittent and uncertain characteristics, high penetration of renewable energy will cause voltage variation and bring the dramatic impact to the operation stability of regional power system. According to the TPC's (Taiwan Power Company) regulation, the voltage variation is limited to below 3% for renewable power generation equipment connecting to the distribution system. It will affect installation capacity and penetration ratio of the solar systems and wind power generation systems in a region. In order to enhance the integration of the distributed generation into regional grid, and to increase the penetration ratio of renewable energy, it is very important to develop microgrid and virtual power plant technology. The Taiwan's first outdoor microgrid, INER microgrid, was built in Longtan township, Taoyuan County, Taiwan, and was connected to TPC distribution feeder in 2013. The research topics include energy management system (EMS), resilient control of distribution feeder with microgrid, multi-level bi-directional inverter for BESS. The EMS was also applied to the remote offshore Dongjiyu Island microgrid to achieve 92.8% penetration rate from renewable energy generation.



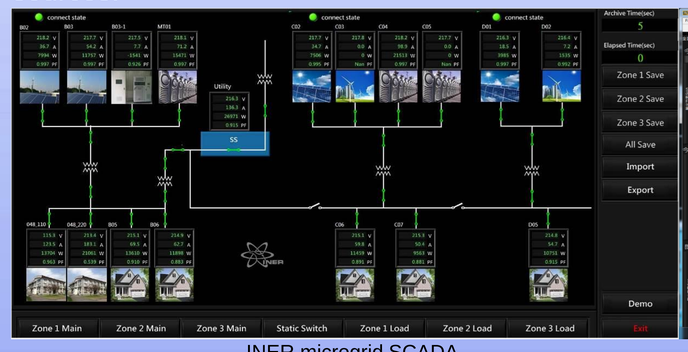




Achievement

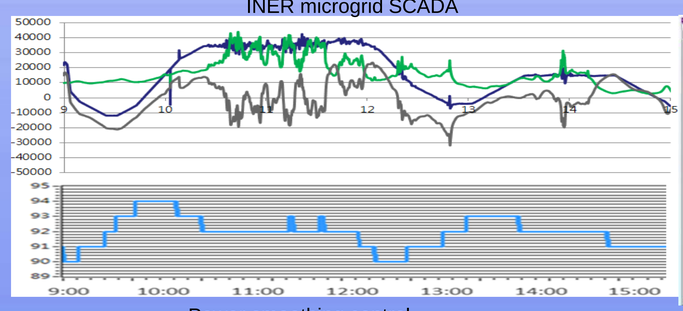
Energy Management System

The EMS of the INER microgrid can integrate RES, MT, DG, and BESS to supply power during the grid connected operation. The BESS is charged or discharged to reduce the rate of change of power generation from RES in the microgrd to achieve smoothing power control. The Feeder Dispatch Control System (FDCS) of Taipower Company (TPC) can dispatch the microgrid power output up to 100 kW to provide ancillary service. The reactive power compensation program is developed to stabilize grid voltage by modulating the BESS. During emergency state of the Taipower system, the microgrid is capable to operate at island mode for more than 100 hours. In the islanding operation, the power output of MT, DG, and ESS are scheduled in ahead of day based on the weather forecast and load prediction. The maximum penetration rate of renewable power generation reached 135 %, and 54% of total power consumption was from renewable energy sources.

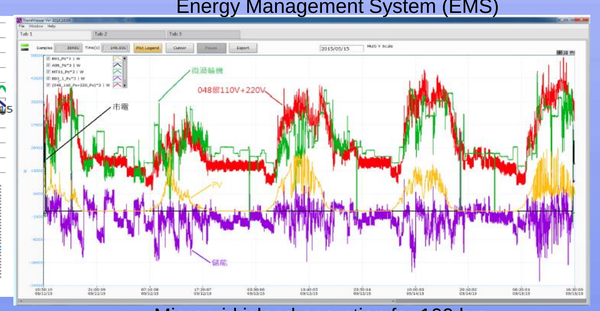


INER microgrid SCADA

Energy Management System (EMS)



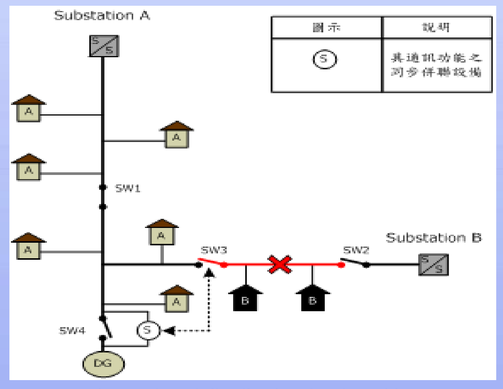
Power smoothing control



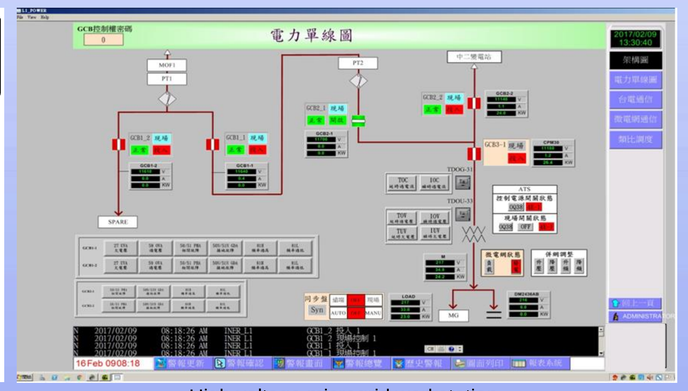
Microgrid island operation for 100 hrs

Resilient Control of Distribution feeder with Microgrid

The microgrid may not be able to reconnect to the distribution system during performing load transfer of distribution feeders, and even cause outage of the distribution system due to synchronization problem. The high voltage microgrid workstation is used to receive dispatching commands from FDCS, and the distribution automation system (DAS) is designed by adding smart switches to achieve resilient control of the microgrid for automatically transferring the power sources to the normal feeder so as to increase the power supplying stability of the overall system. The reliability analysis is also performed to evaluate the unavailability of the INER microgrid. It is found that the outage time of loads in the microgrid with resilient control can be significantly reduced.



Load transfer of distribution feeder with DG



High voltage microgrid workstation

Dongjiyu Island Microgrid

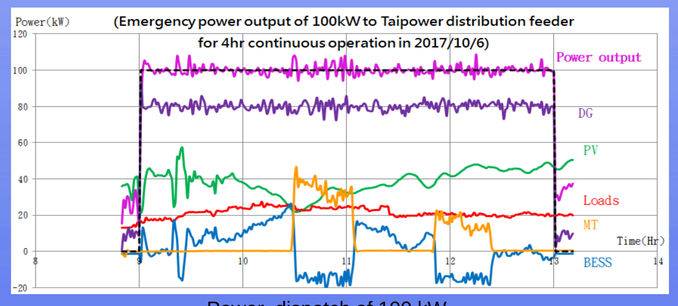
Objective

- Increase the electricity from renewable energy
- Reduce the electricity from fuels
- Enhance the power quality
- Pay the way to carbon free Island

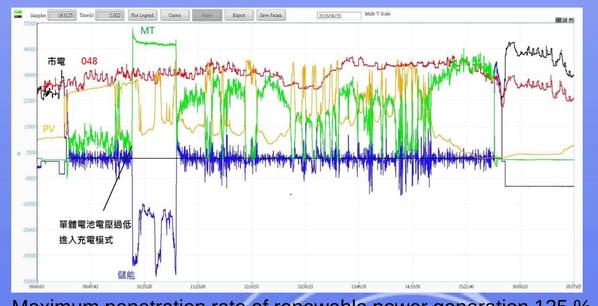
Energy Management System

- Generation Prediction
- Load Prediction
- Remote Monitoring and Control
- Energy Dispatch
- Demand Control
- Unbalance Power Flow Control

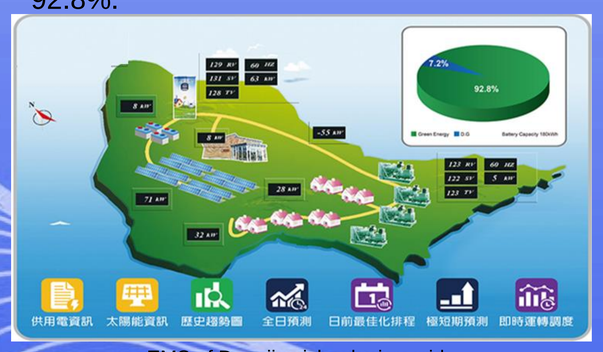
Stage 1 (2015)：The PV system began to commit with the DGs.
Stage 2 (2016)：The smart inverters were installed to PV and BESS system. In addition, the PMS in the SCADA was set to remote control the system power output.
Stage 3 (2017) ：μEMS was developed to perform perdition of RES and loads, scheduling the output of ESS and DGs, frequency regulation and voltage control, so as to increase stability and power quality. The maximum penetration rate of renewable energy generation reached 92.8%.



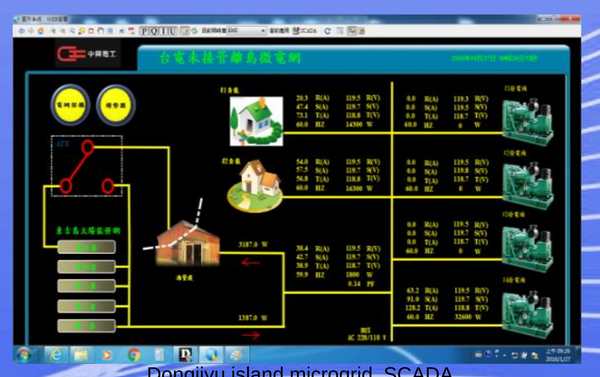
Power dispatch of 100 kW



Maximum penetration rate of renewable power generation 135 %



EMS of Dongjiyu island microgrid



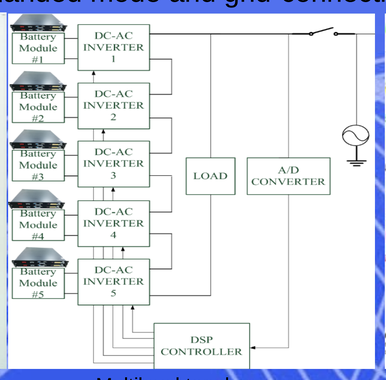
Dongjiyu island microgrid SCADA

Multi-Level Bi-directional Inverter for BESS

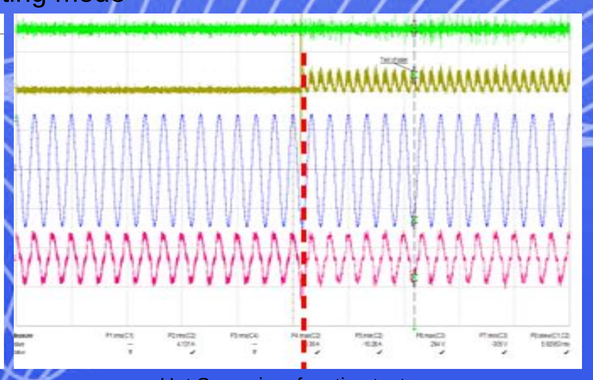
When one battery module is out of order, it can be removed or replaced without shutting down the system and continue its operation stably.

- Hard swapping function for BMS (Battery Management System)
- Independent power control for battery voltage balance
- Multilevel topology with higher output ripple frequency
- Verified both in islanded mode and grid-connecting mode

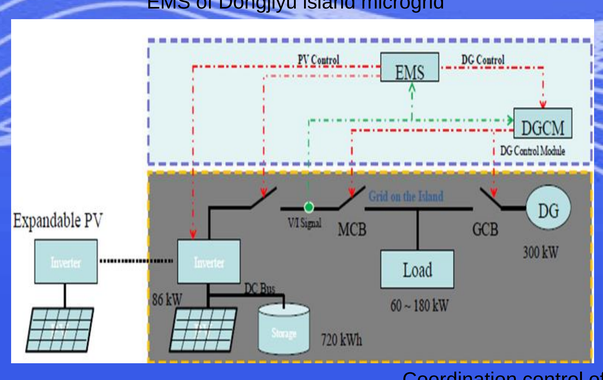
Multi-Level Bi-directional Inverter



Multilevel topology



Hot Swapping function test



Coordination control of PV, Battery and DG