NEDO System Use Case #A1

Energy management of grid-connected microgrid that makes optimum use of city gas as the fuel and mitigates negative effects of intermittent generators on distribution grid.

Version 3.0

Nov 7, 2011

1 Descriptions of Function

1.1 Function Name

Energy management of grid-connected microgrid that makes optimum use of city gas as the fuel and mitigates negative effects of intermittent generators on distribution grid.

1.2 Function ID

System Level Use Case A1

1.3 Brief Description

This use case describes energy management of a grid-connected microgrid system that optimizes the use of city gas while making optimum use of renewable energy and mitigates negative effects on the distribution grid with respect to demand-supply balance and power quality. The microgrid system is connected to the distribution grid at a single point and is controlled by the energy management system (EMS) which maintains the amount of power purchased from the distribution grid (power flow at PCC (point of common coupling)) to contribute to frequency control of the distribution grid and develops a generation schedule in accordance with the load within the microgrid.

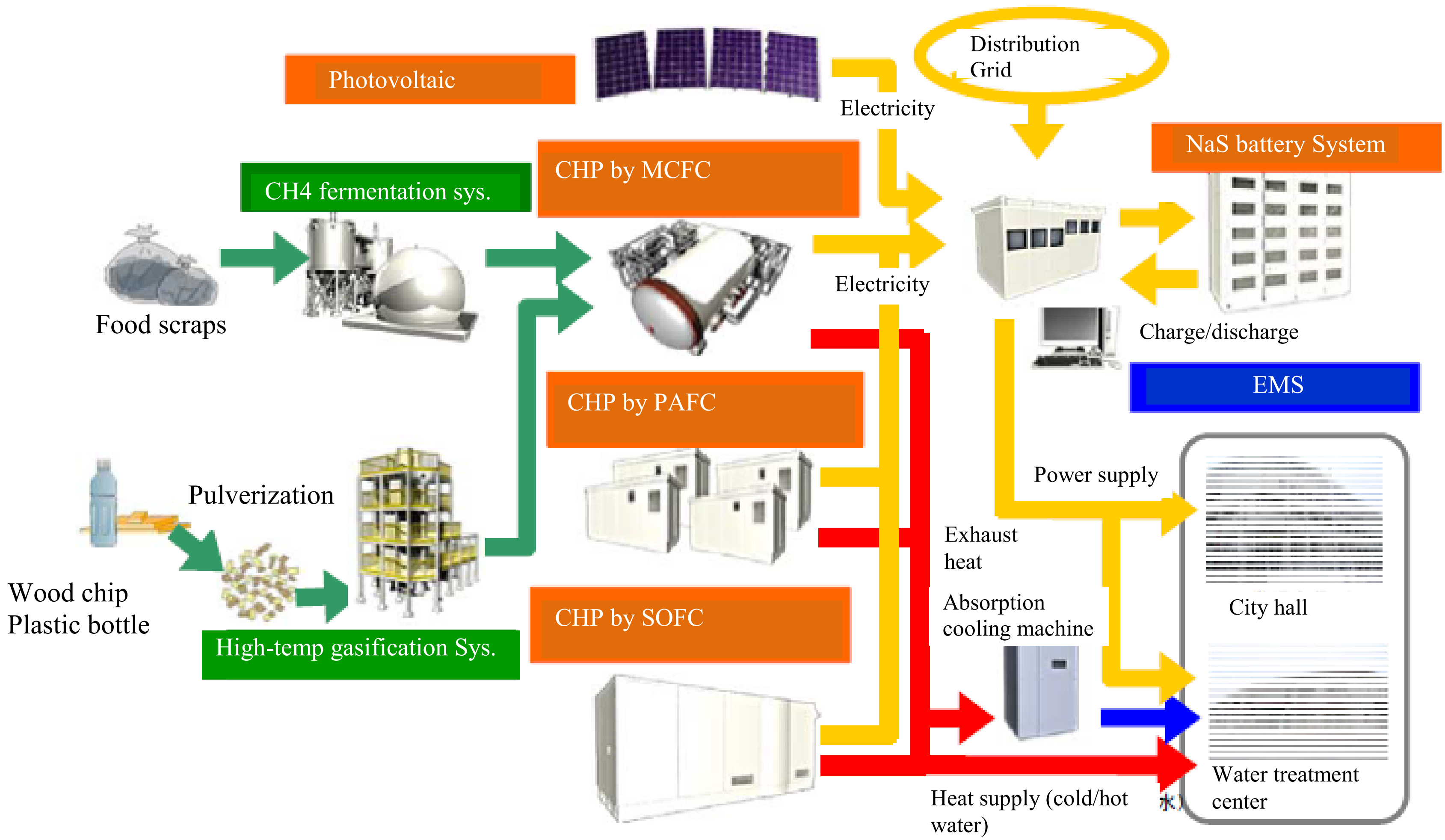

Fig. 1 System flow of demonstration project at Chubu Rinku Toshi in Aichi prefecture, Japan

Note: The use case is described based on the results of NEDO's demonstration project conducted at Chubu Rinku Toshi in Tokoname city, Aichi prefecture, Japan. The aim of EMS is to maintain the power imbalance in supply and demand over a period of 30 minutes within a range of ±3%. The primary power generation sources for this microgrid system are the fuel cells and the PV systems. The fuel cells are supplied by a methane fermentation system and a gasification system. PAFC, MCFC and SOFC were used in the project, where PAFC run under variable operation and SOFC and MCFC under constant output. A Sodium sulfur (NaS) battery is used for storage within the supply system; it plays an important role in balancing supply and demand.

1.4 Narrative

This use case describes energy management of a grid-connected microgrid system that optimizes the use of city gas while making optimum use of renewable energy and mitigates negative effects on the distribution grid with respect to demand-supply balance and power quality. The microgrid system consists of distributed energy resources (DER) and loads that are connected to the distribution grid at a single point (PCC) and controlled by an energy management system (EMS) which maintains the amount of power purchased from the distribution grid (power flow at PCC) to contribute to frequency control on the distribution grid and develop a generation schedule in accordance with the load within the microgrid.

The DER and customers are connected via dedicated power line and public communication line. The using a two-way ICT communication network and the EMS, the microgrid can be managed to mitigate negative effects on power grid while making optimum use of renewable energy.

EMS develops generator scheduling implemented on the previous day in consideration of power demand and PV output forecast based on weather forecast and past power demand records data. On the day, EMS commands power dispatch to controllable fuel cell system and battery system in 1-min. intervals in order to complete simultaneous power balancing control in consideration of actual power demand, PV output and generation scheduling result done on the previous day. In addition, local control of battery is implemented to maintain power flow from distribution grid at the PCC to the planned certain value on the second time scale.

The functions of the EMS are realized in three steps:
Step 1- Generation scheduling implemented on the previous day,
Step 2- Simultaneous power balancing control dispatched on the day in 1-min. intervals, and
Step 3- Local control of battery to maintain power flow from distribution grid at the PCC to the planned certain value on the second time scale .

The EMS does not control customers but only controllable DER.

Step 1: Generation scheduling

Generation scheduling for the next day makes optimum use of city gas and purchased power from the distribution grid, in accordance with the result of the forecast of demand (power and heat) and PV power generation in the microgrid which is based on the next day's weather forecast information as well as past measurements. The power purchased from the distribution grid can be changed up to three times a day. It can also be based on automatic scheduling by the EMS adding various constraint conditions or provided with the value artificially by operator.

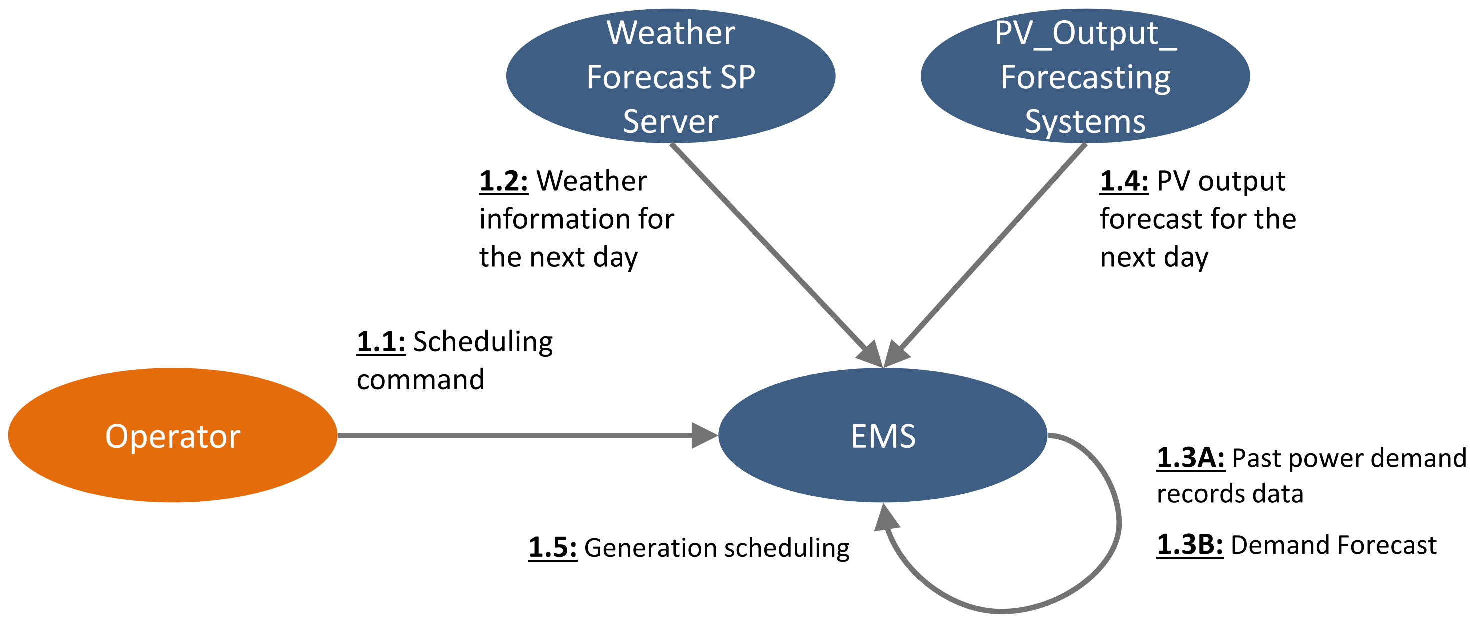

Fig. 2 Diagram of Step1

Step 2: Balancing control

Control is maintained on generating equipment in 1-min. intervals in order to eliminate the difference between the forecasted demand and power generation values (Step 1) and the actual values and to mitigate negative effects on the distribution grid on demand-supply imbalance. It is designed to perform balancing control to keep the deviation between load and supply for 30 minutes within +-3% of the target value.

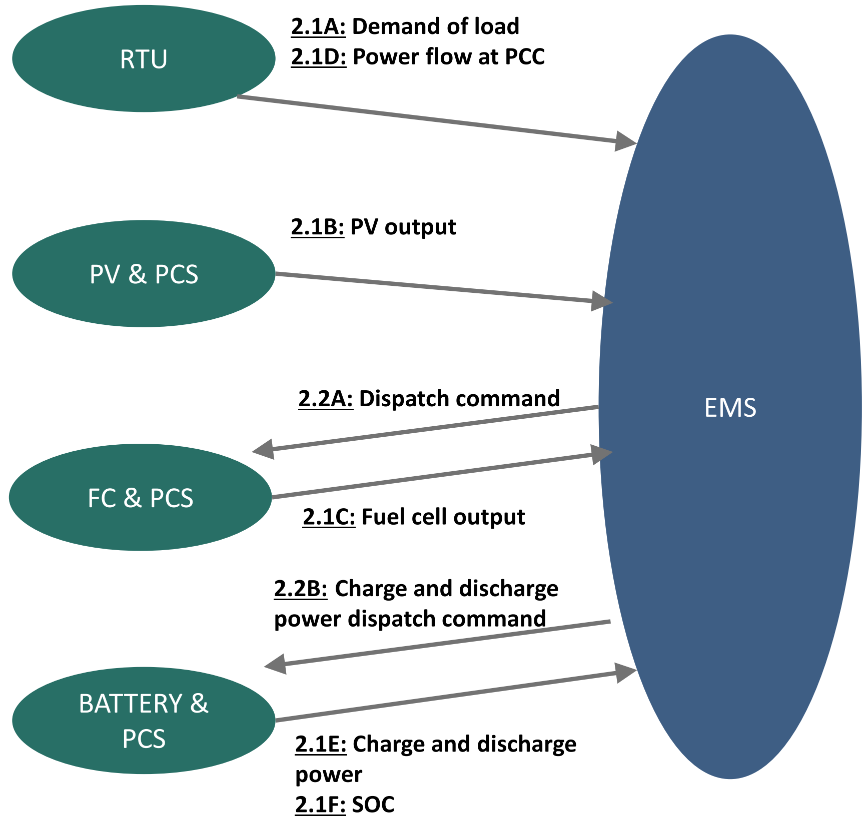

Fig. 3 Diagram of Step2

Step 3: Local control of battery

Local control of battery is implemented to maintain purchased power from distribution grid at the PCC to the planned certain value and mitigate negative effects on the distribution grid on power quality. In this step, power flow at the PCC are monitored every few seconds to determine the output value of the storage battery with consideration of power purchasing from the distribution grid dispatched in every minute.

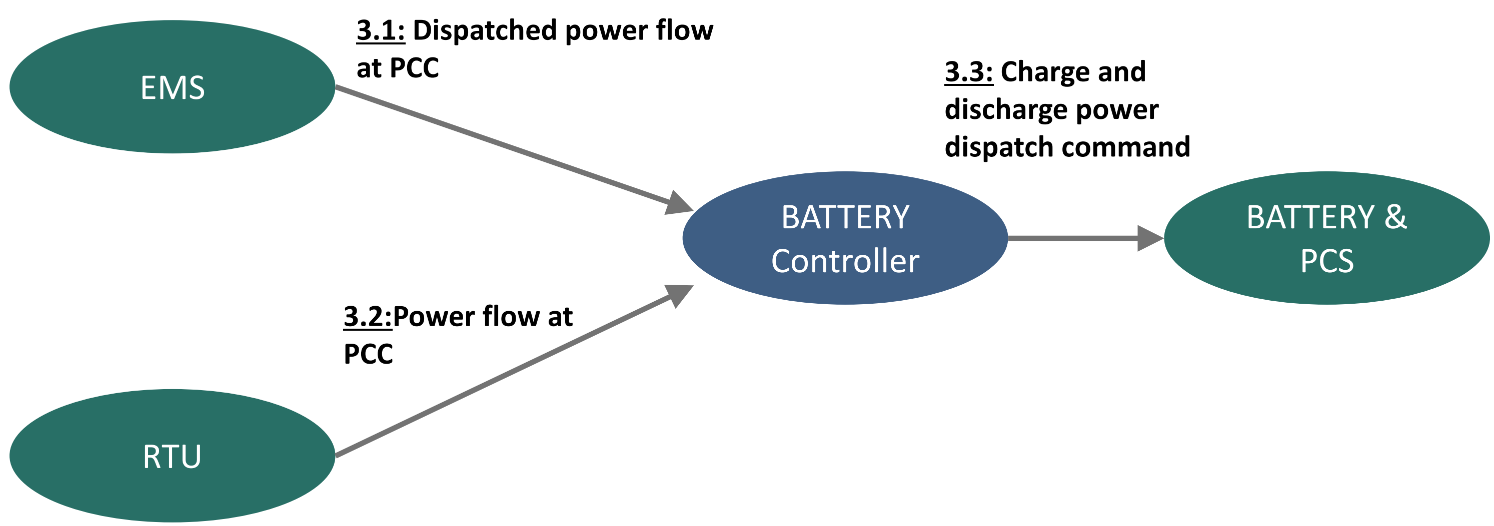

Fig. 4 Diagram of Step3

<Acronyms>

EMS	Energy Management System
DER	Distributed Energy Resources
FC	Fuel Cell
ICT	Information and Communication Technology
MCFC	Molten Carbonate Fuel Cell
PAFC	Phosphoric Acid Fuel Cell
PCC	Point of Common Coupling

PCS	Power Conditioning System
PV	Photovoltaic
RTU	Remote Terminal Unit
SOC	State of Charge

1.5 Actor (Stakeholder) Roles

Grouping (Community) '		*Group Description*
Actor Name	*Actor Type (person, organization, device, system, or subsystem)*	*Actor Description*
EMS	System	Energy Management System for the microgrid. EMS has the functions of monitoring, control and scheduling of the microgrid.
PV_Output_Forecasting Systems	System	The system that forecasts the PV output in every one hour of the next day based on metrological data.
Weather forecast SP server	System	Weather forecast information, which is indispensable for developing generation scheduling, is provided by weather forecast service provider.
RTU	Device	Device to measure the demand of load and the output of generator on a real-time basis.
FC&PCS	Device	Fuel cell and PCS. Control signals are sent from EMS to PCS.
BATTERY & PCS	Device	Battery and PCS. Control signals are sent from EMS to PCS.

Grouping (Community) ’		*Group Description*
Actor Name	*Actor Type (person, organization, device, system, or subsystem)*	*Actor Description*
BATTERY Controller	System	Controller of BATTERY & PCS. Generates power dispatch command for BATTERY & PCS.
PV & PCS	Device	PV and PCS.

1.6 Information exchanged

Information Object Name	*Information Object Description*
Execute scheduling command	Command issued automatically. With this command, development of generation scheduling is started.
PV output forecast for the next day	PV output forecast for the next day prepared based on the weather information for the next day.
Weather information for the next day	Hourly weather, amount of solar radiation and temperature for the next day.
Past power demand records data	Database of past power demand records data.
Demand forecast	Demand forecast based on the weather forecast and past demand patterns.
Generation scheduling	Generation scheduling for fuel cells and batteries generated by EMS based on the PV output forecast and weather information for the next day and the past power demand records data.
Power consumption of load	Real time power consumption of load.
PV output	Real time output of PV.

Information Object Name	*Information Object Description*
Fuel cell output	Real time output of fuel cell.
Power flow at PCC	Real time value of power flow at PCC (point of common coupling).
Dispatched power flow value at PCC	Dispatched power flow value at PCC calculated by EMS in consideration of the optimum operation schedule and the conditions for operation under 30-min. simultaneous balancing control.
Charge and discharge power	Real time charge and discharge power of battery.
SOC	Real time SOC (State of Charge) of battery.
Dispatch command	Dispatch command value of fuel cell calculated by EMS.
Charge and discharge power dispatch command	Charge and discharge power dispatch command value of battery calculated by EMS or the battery itself.

1.7 Activities/Services

Activity/Service Name	*Activities/Services Provided*
Generation scheduling	Generation scheduling for fuel cells and batteries are generated based on the PV output forecast and weather information for the next day and the past power demand records data.
Generation of dispatch value	In order to implement 30-min. balancing, output dispatch value for fuel cells and charge and discharge dispatch value for batteries are generated based on the generation scheduling and the actual imbalance of supply and demand.

1.8 Contracts/Regulations

Contract/Regulation	*Impact of Contract/Regulation on Function*
N/A	

Contract/Regulation	Impact of Contract/Regulation on Function					
Policy	From Actor	May	Shall Not	Shall	Description (verb)	To Actor
N/A						

Constraint	Type	Description	Applies to
N/A			

2 Step by Step Analysis of Function

2.1 Steps to implement function – Energy management of grid-connected microgrid

2.1.1 Preconditions and Assumptions

Actor/System/Information/Contract	Preconditions or Assumptions
Microgrid Equipment Data and Range	Equipment data and operational range has already been determined in database or by manual entry.
Optimization mode	Optimization mode can be selected from minimization of CO_2 emission, maximization of energy efficiency or minimization of cost. The mode is selected by operator in advance.
Purchasing plan	Power from distribution grid can be changed up to three times a day. It can also be based on automatic scheduling by EMS adding various constraint conditions or provided with the value artificially by operator.
EMS	EMS has already prepared the day's optimum generation schedule on the previous day.(Step 1)
EMS	EMS dispatches the target value for active power output of fuel cell and battery every minute to

Actor/System/Information/Contract	*Preconditions or Assumptions*
	implement 30-min. balancing based on the actual demand and generation results, the records of power purchase from distribution grid and the SOC of battery.
Battery	Control is effective when the SOC of battery is in the range of 10 – 85%, and is carried out at second-scale intervals.

2.1.2 Steps

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environment
Step 1: Generation scheduling									
1.1	By 8:00 of the previous day	EMS	Execute Scheduling command	EMS starts generation scheduling automatically.	EMS	EMS	Scheduling command		
1.2	8:00 of the previous day	EMS	Acquisition of weather information for the next day	EMS acquires weather information.	Weather forecast SP server	EMS	Weather information for the next day		
1.3 A	10:00 of the previous day	EMS	Acquisition of past power demand records data	EMS acquires past power demand records data.	EMS	EMS	Past power demand records data		
1.3 B		EMS	Development of demand forecast	EMS conducts demand forecast based on the weather forecast and past demand patterns.	EMS	EMS	Demand forecast		

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environment
1.4		EMS	Acquisition of PV output forecast	EMS acquires the forecast value from PV output forecasting unit.	PV_Output_Forecasting Systems	EMS	PV output forecast for the next day		
1.5	11:00 of the previous day	EMS	Generation scheduling	EMS prepares the optimum generation schedule for the next day at 30-min. intervals.	EMS	EMS	Generation scheduling		
Step 2: Balancing control									
2.1 A	On-going monitoring data by EMS	EMS	Acquisition of demand of load	EMS acquires demand of load.	RTU	EMS	Demand of load	TCP/IP	
2.1 B	On-going monitoring data by EMS	EMS	Acquisition of PV output	EMS acquires PV output.	PV & PCS	EMS	PV output	TCP/IP	
2.1 C	On-going monitoring data by EMS	EMS	Acquisition of output of fuel cell	EMS acquires output of fuel cell.	FC & PCS	EMS	Fuel cell output	TCP/IP	
2.1 D	On-going monitoring data by EMS	EMS	Acquisition of power flow at PCC	EMS acquires power flow at PCC.	RTU	EMS	Power flow at PCC	TCP/IP	
2.1 E	On-going monitoring data by EMS	EMS	Acquisition of power of battery	EMS acquires power of battery.	BATTERY & PCS	EMS	Charge and discharge power	TCP/IP	

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environment
2.1F	On-going monitoring data by EMS	EMS	Acquisition of battery SOC	EMS acquires battery SOC.	BATTERY & PCS	EMS	SOC	TCP/IP	
2.2 A		EMS	Dispatch command	EEMS provides fuel cell with dispatch command based on supply/demand imbalance and optimum generation scheduling.	EMS	FC & PCS	Dispatch command	TCP/IP	
2.2 B		EMS	Charge and discharge power dispatch command	EMS provides battery with power dispatch command based on supply/demand imbalance and optimum generation scheduling.	EMS	BATTERY & PCS	Charge and discharge power dispatch command	TCP/IP	
Step 3: Local control of battery									
3.1	Every minute	BATTERY Controller	Acquisition of dispatched power flow at PCC	BATTERY Controller acquires EMS' dispatched power flow at PCC.	EMS	BATTERY Controller	Dispatched power flow at PCC	TCP/IP	
3.2	Every few seconds	BATTERY Controller	Acquisition of power flow at PCC	BATTERY Controller acquires power flow at PCC.	RTU	BATTERY Controller	Power flow at PCC		

#	Event	Primary Actor	Name of Process/Activity	Description of Process/Activity	Information Producer	Information Receiver	Name of Info Exchanged	Additional Notes	IECSA Environment
3.3	Every few seconds	BATTERY Controller	Charge and discharge power dispatch command	BATTERY Controller provides power dispatch command so that the power flow at PCC conforms to the dispatch value.	BATTERY Controller	BATTERY & PCS	Charge and discharge power dispatch command		

2.1.3 Post-conditions and Significant Results

Actor/Activity	*Post-conditions Description and Results*
FC & PCS BATTERY & PCS	Output is controlled to implement 30-min. balancing.
Microgrid System	30-min. balancing is achieved in the microgrid system.
Power flow at PCC	Power flow value at PCC becomes constant.

2.2 Architectural Issues in Interactions

FUTURE USE

2.3 Diagram

FUTURE USE

3 Auxiliary Issues

3.1 References and contacts

ID	Title or contact	Reference or contact information
[1]	Supply and Demand Control of Distributed Generators in a Microgrid (INTELEC 2008)	Toyonari Shimakage, Jiro Sumita (NTT facilities, Inc.), Noriyuki Uchiyama (Hitachi, Ltd.), Takeyoshi Kato, Yasuo Suzuoki (Nagoya Univ.) G.H.Y. Bldg., 2-13-1 Kitaotsuka, Toshima-ku, Tokyo 170-0004 shimak24@ntt-f.co.jp

3.2 Action Item List

ID	Description	Status
N/A		

3.3 Revision History

No	Date	Author	Description
0.0	8-26-2011	H. Iwasaki H. Maejima	Draft for Review 1
1.0	09-09-2011	H. Iwasaki	Draft for Review 2
2.0	Oct 14 2011	H. Iwasaki H. Maejima	Draft for review 3
3.0	Nov 7 2011	T. Shimakage J. Sumita K. Nishioka H. Iwasaki H. Maejima J. Reilly	Final Version