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Energy monitoring based on human activity in the workplace

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Abstract. Human behavior is the most important factor in order to manage energy usage. Nowadays, smart house technology offers a better quality of life by introducing automated appliance control and assistive services. However, human behaviors will contribute to the efficiency of the system. This paper will focus on monitoring efficiency based on duration time in office hours around 8am until 5pm which depend on human behavior atb the workplace. Then, the correlation coefficient method is used to show the relation between energy consumption and energy saving based on the total hours of time energy spent. In future, the percentages of energy monitoring system usage will be increase to manage energy in efficient ways based on human behaviours. This scenario will lead to the positive impact in order to achieve the energy saving in the building and support the green environment.

1. Introduction

Recently, human activity has been used to monitor the energy usage performance for smart house. Smart home is one of a universal computing in which the information-perceiving and information-processing units remain invisible in the surroundings to create a pervasive environment. People spend a significant amount of time in their houses, and this has drawn researchers to promote integration of all possible services with traditional homes [1]. Besides that, smart home is a study of human psychology to create a pervasive environment employing ambient intelligence [2].

Human habit cannot be controlled because it changes according to our life. Human activity has been critical information since knowing what activities are undertaken is well important for judging if energy consumed by appliances is well spent by users [4]. Besides that, an estimation of the occupant's location can be modelled as the belief in the fact that he/she is located at position, x at the instant, t. This is depend on the time to reflect the changes in activities during the day or week. The information from human activity is an important clue for providing an energy saving service.

Wireless Enabled Electricity Manger (WEEMAN) is an intelligent control device reported in [3]. This system can monitor the energy consumption of a single device or a set of devices. Smart meter acts as the central control node in which availability based management algorithm. This algorithm learns about the usage patterns of the appliances, collects the information such as the real time average power of appliances from WEEMAN to generate efficient energy load patterns. The algorithm will provides a unique attribute for the user to set the expected monthly electricity bill amount and proactively control the operation of the all appliances according to the amount [3].

Furthermore, it is also preferable to know the relationship between a context and its energy consumption for a smart home utilizing context-aware energy saving besides the inferred contexts [4]. So, the reason by ignoring the relationship between a user context and its energy consumption often makes smart homes hard to find effective energy saving policies without sacrificing user comfort.

Smart home energy management system will monitor, manage and control the functions of the home appliances to reduce the monthly electricity bill [3]. The major benefits of smart house to consumers are the ability to incorporate energy management types through lighting, air conditioning and home appliances. Lighting is important for humans to see and do a work. The perfect lighting system when have auto control lighting so that will be dimmable light and bright light depend on situation of human activity and need.

Human activities are often discussed about the daily routine for workers/staffs at office or man and wife in the smart house which rarely discuss in Malaysia. The focuses on energy efficiency based on workers/staffs behaviour at working place or office will be investigate in this paper. Then, the correlation coefficient of energy saving performance based on total energy usage hours of time spent will be compute and analyze. In this paper the relation of energy consumption and energy saving in the workplace for every week are limited to 5 days. Furthermore, the proposed energy monitoring system will focuses mainly on lighting control, air-conditioner (HVAC) and some electrical appliances only.

2. Case Study

Human always moved around the office because each person has a different image and personality. So, there also different behaviours of energy usage can be categorized in similar working place. The energy monitoring system required various of sensors to detect a motion and temperature in monitored area. In an office environment, workers usually would like to use 3 rooms which are office room, living room and restroom. So, we proposed the monitored working space with 1 Office Room, 1 Living Room, and 2 Restroom. Each room dimension is design by using the Sweet Home Software. The figure 1 and table 1 shows the office environment and dimensions area of proposed monitored working place.

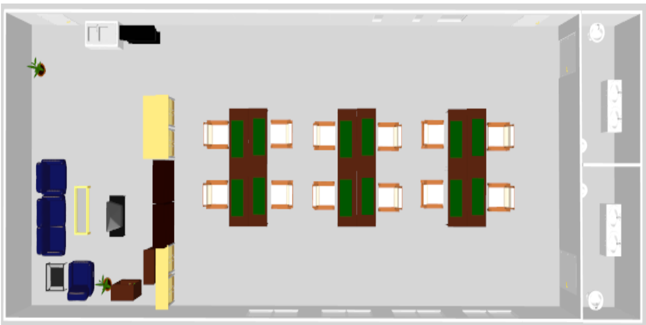


Figure 1. Proposed monitored working space environment

In a working environment, living room is used by staff to get some rest such as to make coffee for tea break. There are two restroom for male and female in order to provide comfort working environment place for workers.

Table 1. Dimension area proposed for each room

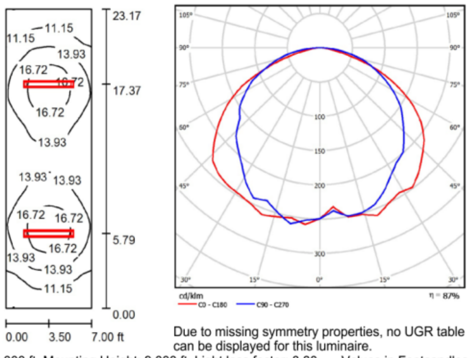
Rooms	Office Room	Living Room	Restroom	Total
Area/m^2	104.3	35.0	14.6	153.9

There are 10 unit sensors are place in selected position in order to provide an accurate information about the inhabitant's location. Occupancy sensor is proposed instead of motion sensors, since the occupancy sensor can detect the movement accurately and usually preferred for security system. Occupancy sensors can be switched automatically by detecting any movements within a coverage space. Occupancy sensors can be divided into two: Passive Infra Red (PIR) and PIR Ultrasonic. PIR will detect motion by sensing temperature profile change which is suitable for large body. PIR ultrasonic is more suitable to detect tiniest movement to ensure maximum effectiveness for almost every application in every space. Table 2 shows the quantity of sensors for each room.

Table 2. Total sensor for each room

Total	Office Room	Living Room	Restroom	Target
6	3	1	2	Light Control
4	3	1	0	HVAC

Each room is simulated by using DIALux software to calculate the power required for lighting. The DIALux software allow the users to choose any type of lamp which suitable for the simulated area. Figure 2 shows simulated lighting power in the restroom by using DIALux software. The air-conditioner and home appliance capacity were calculated according to the Consumer Guide to Home and the General Electric as proposed in [5]. The total power consumption of each room for lighting, air conditioning and home appliances are simulated in a KWH/day.



Due to missing symmetry properties, no UGR table can be displayed for this luminaire.

Height of Room: 9.000 ft, Mounting Height: 9.000 ft, Light loss factor: 0.80 Values in Footcandles, Scale 1:91

Surface	ρ [%]	E_{av} [fc]	E_{min} [fc]	E_{max} [fc]	u0
Workplane	/	14	8.20	18	0.599
Floor	20	10	7.12	12	0.683
Ceiling	80	3.79	2.40	4.93	0.633
Walls (4)	50	8.43	2.99	25	/

Workplane:
Height: 2.493 ft
Grid: 64 x 32 Points
Boundary Zone: 0.000 ft
Illuminance Quotient (according to LG7): Walls / Working Plane: 0.671, Ceiling / Working Plane: 0.277.
Proportion of points with less than 400 lx (for IEQ-7): 100.00%.

Luminaire Parts List

No.	Pieces	Designation (Correction Factor)	Φ (Luminaire) [lm]	Φ (Lamps) [lm]	P [W]
1	2	LUMICENTER CCN07-E132 (1.000)	2361	2700	36.0
			Total: 4721	Total: 5400	72.0

Specific connected load: 0.44 W/sq ft = 0.32 W/sq ft/10 fc (Ground area: 162.17 sq ft)

Figure 2. Simulated lighting power by using DIALux software

3. Proposed Scenario

The next step is to monitor the human behaviour on appliances and devices and model in term of usage time duration. Each person was divided into three categories: Person A is refer to worker which is like to do his work in an office. Person B is refer to worker which like to do his work in an office and outside of the office. While, Person C is refer to worker which is like to do his work at outside of the office for most of the time.

The input given is the time where the system will be ‘start’ and ‘stop’. All the information about that scenario created will be stored in the microcontroller. When the Person A is entering the office area, the light and air-conditioner are automatically switch ‘ON’ in main office 15 minutes before to standby state. If that person has not shown in an office within next 15 minutes, the system will ‘recheck’ and ‘call back’ later at the same time for implementing the others task. The air conditioner is used in living and office room only.

Scenario management information allows users to define a set of behaviour rules. A lot of sequences can be implemented according to the habitant’s age and its social status. The proposed scenario will focuses on a working time in office. Table 3 shows the proposed activity for 3 types of workers. Type A is for the busy worker, type B for normal worker and type C for off work worker. The 9 normal worker’s steps and time spent for 3 types of workers is proposed in Table 3.

Table 3. Proposed Scenario

Wrong Behaviors	Action	A	B	C	Time	Step
	Office Room is ON	Enters Office			At 8 o’clock	1
Office Room is left on for 4 hours	Living Room is ON	Enters Living Room			8-8.30	2
	Living Room is OFF Office Room still ON		Enters Office		At 8.30 o’clock	
Living Room is left on for 30 minutes	Restroom is ON Office Room still ON	Enters Restroom	Enters Living Room		8.30-8.45	3
	Restroom is OFF	Start Working at her/him desk			At 8.45	
	Office Room still ON		Start Working at her/him desk	Enter Office Start Working at her/him desk	At 9 o’clock	
	Restroom is ON Living Room is ON		Enters Restroom	Enters Living Room	At 10 o’clock	4
Living Room is left on for 30 minutes	Restroom is OFF				At 10.15	
	Living Room is OFF Office Room still ON	Still Working	Continue Working	Continue Working	At 10.30 o’clock	

	Restroom is ON			Enters Restroom	11.30 - 11.45	5
	Restroom is OFF			Leave office go to lunch	At 11.45 o'clock	
	Office Room is OFF	Leave office go to lunch	Leave office go to lunch		At 12 o'clock	
	Office Room is ON	Enters Office			At 2 o'clock	6
Office Room is left on for 3 hours	Office Room still ON		Enters Office	Enters Office	At 2.15 o'clock	
	Living Room is ON			Enters Living Room	3-3.15	7
Living Room is left on for 15 minutes	Living Room is OFF	Still Working	Still Working	Continue Working	At 3.15 o'clock	
	Restroom is ON	Enters Restroom			4-4.15	8
	Restroom is OFF				At 4.15 o'clock	
	Living Room is ON		Enters Living Room	Enters Living Room	4.30-5.00	9
Living Room is left on for 30 minutes	All rooms are OFF	Leave office to go back	Leave office to go back	Leave office to go back	At 5 o'clock	

The proposed human habits which is cannot be controlled and depend on personal life is tabulated in Table 3. Thus, the difference of power consumption related to the total hours spent and saving in each room is recorded in KWH. Table 4, 5, and 6 represents the number of duration time spent in each person in every room for 9 working behaviour's steps that proposed in Table 3. Equation (1),(2) and (3) are used to get the result for calculation in table 4, 5 and 6. The all equation is very help to complete the result for power saving, power consumption and saving in cost.

$$\text{otal Power, kWh} = \text{otal Time Spent for each room (hour)x Total Power per day, kWh} \quad (1)$$

$$\text{Power Consumption, kWh} = \text{ime Spent(hour)x Total Power use per hour, kWh for each room} \quad (2)$$

$$\text{Power Saving, kWh} = \text{otal Power, kWh} - \text{Power Consumption, kWh} \quad (3)$$

$$\text{Saving in cost (RM)} = \text{Power Saving, kWh x RM 0.218 per unit (tariff rate in Malaysia)} \quad (4)$$

Table 4. Power per day (Total Power per day = 77.299 kWh)

	Power Saving, kWh	**Power Consumption, kWh**	**Saving in cost (RM)**
A	30.599	46.7	6.671
B	36.471	40.828	7.951
C	39.715	37.584	8.658

Table 5. Power per week (Total Power/week = 386.495 kWh)

	Power Saving, kWh	**Power Consumption, kWh**	**Saving in cost (RM)**
A	152.995	233.5	33.353
B	182.355	204.14	39.753
C	198.575	187.92	43.289

Table 6. Power per month (Total Power per month = 1545.98 kWh)

	Power Consumption, kWh	**Power Saving, kWh**	**Saving in Cost, RM**
AAAA	934	611.98	133.412
AAAB	904.64	641.34	139.812
AAAC	888.42	657.56	143.348
AABB	875.28	670.7	146.213
AABC	859.06	686.92	149.749
AACC	842.84	703.14	153.285
ABBB	845.92	700.06	152.613
ABBC	829.7	716.28	156.149
ABCC	813.48	732.5	159.685
ACCC	797.26	748.72	163.221
BBBB	816.56	729.42	159.014
BBBC	800.34	745.64	162.55
BBCC	784.12	761.86	166.086
BCCC	767.9	778.08	169.621
CCCC	751.68	794.3	173.157

4. Result and Discussion

The power consumption calculations in Table 7 are not considered the usage of air-conditioner and also no appliances usage in restroom. So, air –conditioner and the others appliance are usage in office room and living room. This paper also shows total power consumption calculated for home appliances including 12 Personal Computer, 1 LCD Television, 1 Water Heater, 12 Cellphone and 12 MP3 Player. All calculation of power consumption for lighting, air-conditioning and home appliances is shown in table 7. In order that, the result in table 7 is used to calculate the value of power consumption in table 4, 5, and 6 depend on time spent per day, week and month.

Based on figure 3, the result shows that the power consumption and power saving are changes depend on the human behavior. Thus, human behavior is important thing must to think first and control to get the efficient monitoring system. In the several tested data, that will help the people to know when the fixed time a human goes to the restroom and living room, and also how long their take a time in restroom, living room and go outside for off work.

Table 7. Calculation of Power Consumption for each Room

Total	**Office Room**	**Living Room**	**Restroom**	
153.9	104.3	35.0	14.6	**Area/m^2**
0.3040	0.0310	0.2010	0.0720	Light KWH/day
6.1000	5.0000	1.1000	0.0000	HVAC KWH/day
2.1848	1.4928	0.6920	0.0000	Home Appliances KWH/day

From previous data, the total power/month for power consumption, power saving and percentage of power saving/month have been calculated. The figure 3 is show the comparison between power consumption(in kWh), power saving (in kWh) and power saving cost (in RM).

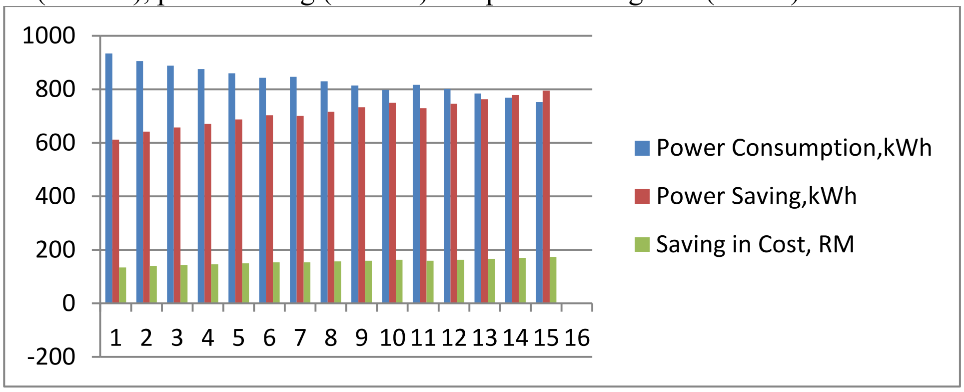


Figure 3. Comparison between power consumption, power saving and power saving in cost

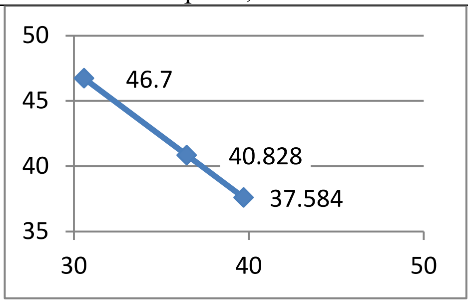
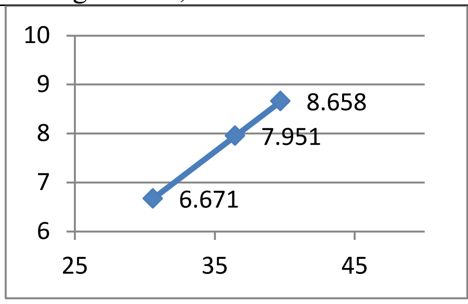
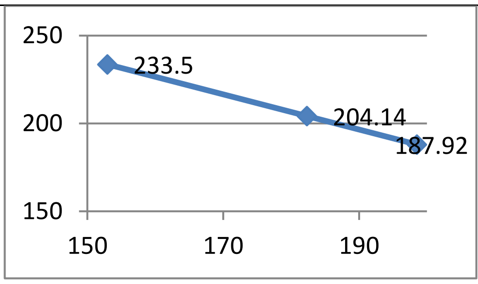
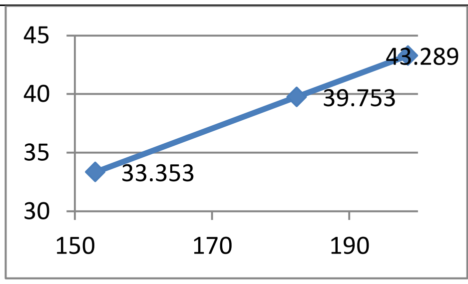
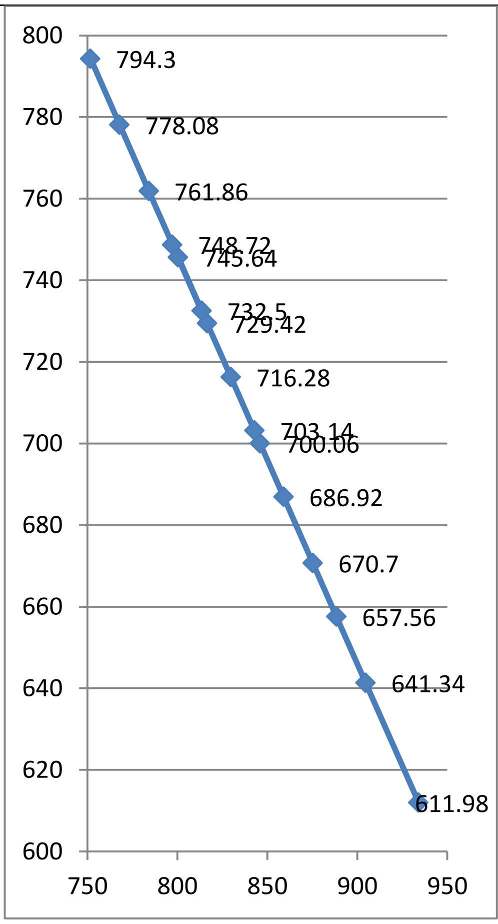
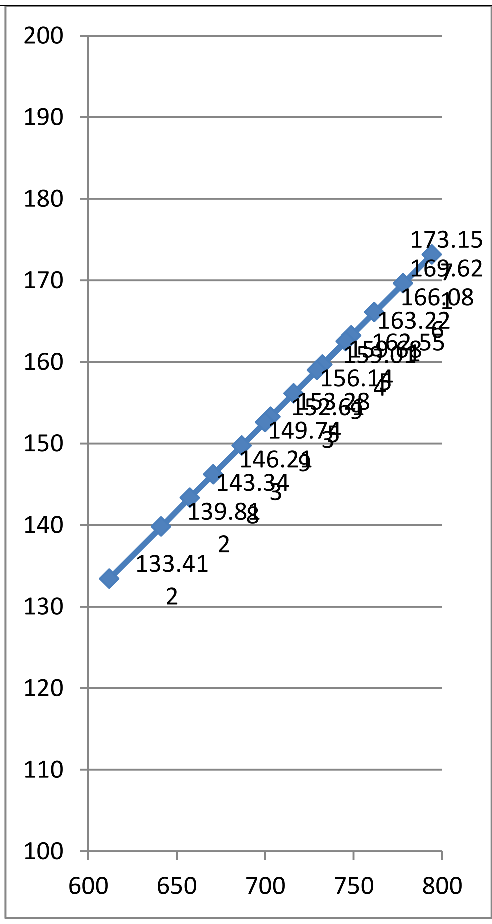
5. Correlation Coefficient of Power Consumption and Power Saving

The correlation statistical method is used to evaluate the relation between the power consumption and the power saving. A correlation coefficient is a single number that describes the degree of relationship between two variables that ranges from -1 to +1, indicating a perfect negative correlation at -1, absence of correlation of zero, and perfect positive correlation at +1 [6]. Table 8 indicates the relation between two random variables (X, Y) according to the correlation coefficient [6]. While, Table 9, show the graph of power consumption versus power saving for per day, per week and per month.

Table 8. Relationship between X and Y

Relationship between X and Y		
r=+1.0	Strong – Positive	As X goes up. Y always also goes up
r=+0.5	Weak – Positive	As X goes up: Y tends to usually also go up
r=0	-No Correlation-	X and Y are not correlated
r=-0.5	Weak – Negative	As X goes up: Y tends to usually go down
r=-1.0	Strong – Negative	As X goes up. Y always goes down

Table 9. Correlation Coefficient for Power Consumption, kWh and Saving in Cost, RM

	Power Consumption, kWh	Saving in Cost, RM
Per day	 r = -1	 r = 0.99
Per week	 r = -1	 r =1
Per month	 r = -1	 r =1

Thus, based on table 9, the relation between power consumption and power saving indicates a strong negative relation (r=-1). This means that when power consumption increases, the power saving will decrease.

6. Conclusion
A proposed scenario is suggested for weekday to minimize power consumption and maximize occupant's energy saving. The results indicate that smart room based on a set of sensors could perform better energy management which is not only an individual need but also for economical target. It is expected that the smart monitoring system based on human behaviour will improve energy efficiency in buildings and raise building user's awareness on green environment. The intention to install more sensitive sensors in order to sense more useful information on human behaviour in the smart room environment can provide more efficiency to the system. The result also shows a strong negative relation between power consumption and power saving in cost.

7. Acknowledgement
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8. References
[1] M. R. Alam, "SPEED: An Inhabitant Activity Prediction Algorithm for Smart Homes",*IEEE Transaction on Systems, Man, and Cybernetics-Part A:Systems and Human*, Vol. 42, No. 4, pp. 985-990, July 2012

[2] M. R. Alam, M. B. I. Reaz, F. H. Hashim and M. A. M. Ali, "Stochastic Analysis of Smart Home User Activities", *Proceedings of International Joint Conference on Neural Networks, San Jose, California, USA*, pp. 21-23, July 31- August5 2012

[3] A. R. Devidas, T. S. Subeesh, and M. V. Ramesh, "Design and Implementation of User Interactive Wireless Smart Home Energy Management System", pp. 1-6, 2012

[4] M-Y. Weng, C-L. Wu, C-H. Lu, H-W. Yeh, and L-C. Fu, "Context-aware Home Energy Saving based on Energy-Prone Context", *IEEE/RSJ International Conference on Intelligent Robots and Systems, Vilamoura, Algarve, Portugal*, pp. 5233-5238, October 7-12 2012

[5] "Wholesale Solar",*Consumer Guide to Home and the General Electric website*, http://www.wholesalesolar.com/StartHere/HowtoSaveEnergy/PowerTable.html

[6] I. I. Attia, and H. Ashour, "Energy Saving Through Smart Home", *The Online Journal on Power and Energy Engineering (OJPEE)*, Vol. 2, No. 3,pp. 223-227

[7] P. Paschke, M. Plonczak, P. Klis, and M. Grunt, "Perspectives of development of integrated monitoring system of power supply and air conditioning equipment towards technical environment equipment monitoring system of the operator", *INTELEC 2008 - 2008 IEEE 30th International Telecommunications Energy Conference*, pp. 1–6, Sep. 2008.

[8] B.H. Ng and Z. A. Akasah, "An Overview of Malaysia Green Technology Corporation Office Building: A Showcase Energy-Efficient Building Project in Malaysia", *Journal of Sustainable Development*, vol. 4, no. 5, pp. 212–228, Sep. 2011.

[9] M. S. Mathavi, D. Vanitha, S. Jeyanthi, and P. Senthil, "The Smart Home : Renewable Energy Management System for Smart Grid Based On ISM Band Communications", *International Journal of Scientific& Engineering Research* , vol. 3, no. 3, pp. 1–8, March, 2012.

[10] A. M. Carreiro, S. Member, P. S. Moura, J. I. Moreno, A. T. De Almeida, S. Member, and J. L. Malaquias, "In-House Monitoring and Control Network for the Smart Grid of the Future", *Innovative Smart Grid Technologies (ISGT Europe), 2011 2nd IEEE PES International Conference and Exhibition on*, pp. 1–7, 2011.