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Efficient Energy Management Using Domotics Controller and Validation Incorporating Lab View in wind/solar/battery Storage Hybrid System

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ABSTRACT

This paper presents an exploration on the effective usage of power using Domotics controller for domestic or small scale buildings in regulation of efficient energy management. LabVIEW has been applied in the validation of load requirement to household appliances. Customers are required to present the energy demand to actively observe and respond to the energy requirements. Hence there is a need to design a smart system that automatically executes all these tasks without any difficulty to the customers, thus an autonomous scheduling and controlling scheme for the electric supply of household appliances and demand of home energy management system (hems) via energy management system for 8.7kw with Domotics controller is presented.

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INTRODUCTION

The generation patterns resulting from the renewable sources may have some similarities with the electricity demand patterns, but they are in general far from being equal. On the other hand, electricity usage increased significantly and became very fluctuating. Demand peaks have to be generated and transmitted, and they define the minimal requirements in the chain. Thus, minimal grid requirements have increased due to the fluctuating demand. Another effect of fluctuations in demand is a decrease in generation efficiency (Sungjin *et al.*, 2014). So the supplemental production is required for this reason to keep the demand and supply in balance, resulting in an even more fluctuating generation pattern for the conventional power plants. Earlier research has been focused on the evaluation of the scheduling of air conditioning or heating devices for temperature control, but only few have been focused on energy management from a power saving perspective of electric loads (Le *et al.*, 2008). The concept of probability has been applied in smart building energy management primarily to predict house occupancy levels. However, reference (Pedrasa *et al.*, 2009) and (Predrasa *et al.*, 2010) has evaluated the on/off scheduling of electric loads based on a predetermined curtailment, without including the characteristics of the electric loads. In addition (Conejo *et al.*, 2010), (Huang *et al.*, 2004), and (Majumdar *et al.*, 1996) has not considered the user satisfaction level to individual loads but just focused only on the cost minimization strategy. All these papers reveal that changes can be done in any part. Hence based on the functionality of the micro grid, the operation is described in terms of Power flow control, demand and machine to machine (M2M) networking (Clarke *et al.*, 2002).

This paper proposes efficient energy management system using Domotics controller incorporating LabVIEW software for validation purpose in wind/PV systems with cost analysis using real time data of solar irradiation and wind speeds of 8.7kW set up.

Domotics controller:

A home automation system integrates electrical devices in a house with each other. The techniques employed in home automation include those in building automation as well as the control of domestic activities, such as home entertainment systems, houseplant and yard watering, pet feeding, changing the ambiance "scenes" for different events (such as dinners or parties), and the use of domestic robots. Devices may be connected through a computer network to allow control by a personal computer, and may allow remote access from the internet. As discussed before, manual participation

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by customers in demand response will not be possible. Some users may be unavailable or may not have the knowledge to appropriately respond to grid signals. The Domotics controller employed in this work acts as a control for on/off of the domestics appliances. By proper utilization of this controller achieves high efficiency, low power consumption and relatively proper energy management. During day time the output of the solar PV cell is used for operation of the appliances and charges the storage devices. Wind energy source also supplies the load during morning when there is no solar output. Hence by optimal use of these sources the regulation of the power supply may be enhanced.

Proposed scheme:

The proposed scheme has wind/solar/battery storage as power supplying elements. Fig 1. Shows the proposed scheme using Domotics controller in the set up. Simulation is done using measurement and automation explorer (LabVIEW). When load is connected, solar power is turned on; excess power is used to charge the battery. If the battery is fully charged, excessive power generated was utilized. When there is shortage of power, battery back-up was used and inerter is turned on. After battery being discharged fully, shortage of power can be compensated from the Grid. From the block diagram it is seen that the output power is given to the Domotics controller which provides the on/off control for the relays and are connected to the loads. Also the supply is given to the loads through the relays. The input of the Domotics controller is fed from the step down transformer. Fig 2. Shows the flowchart of the proposed scheme and the logic written in LabVIEW is based on the flowchart drawn. According to the flowchart, available output power is given to the real-time load control. Power flow forecasting is done for efficient utilization of the renewable resource. Excess power is stored in off-peak storage. When there is power shortage Electricity Board (EB) or grid supply is enabled.

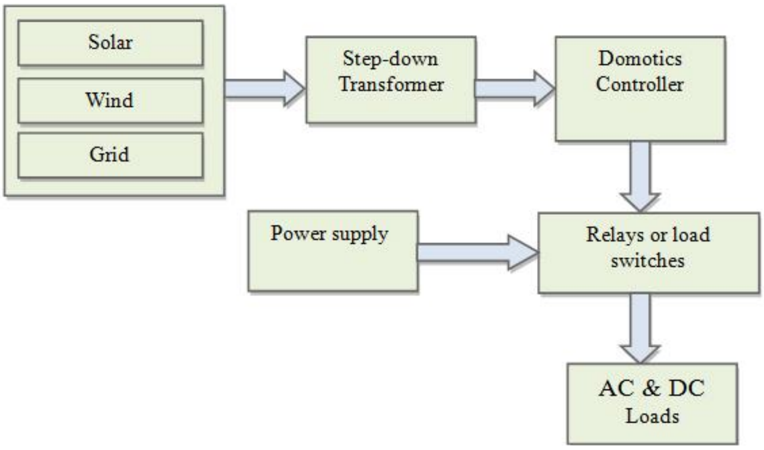

Fig. 1: Block diagram of the proposed scheme.

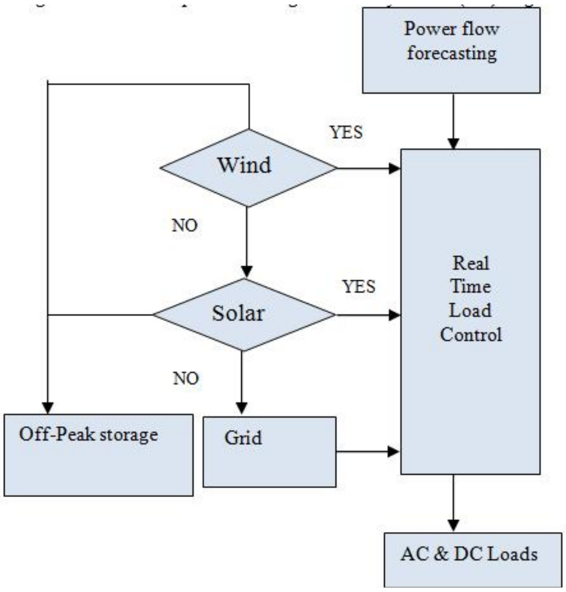

Fig. 2: Flowchart of the proposed scheme.

Load scheduling:

The optimization of energy use of a house with a set of N devices over a total observation period of H has been considered. These appliances are categorized depending on whether or not their operations can be interrupted once they have been activated. The power demand analysis is carried out for a 24-hour period (one day).

The hourly energy requirement for each appliance is quantified in kW and is expressed (Molderink *et al*., 2010) as

$$E_a \triangleq [E_{1,a}, E_{2,a}, \ldots . E_{h,a}] , \forall h \in \{1, \ldots .24\} , \forall a \in N \quad (1)$$

Where $E_{h,a}$ refers to the energy consumption of appliance a in the time slot h. The total hourly energy demand for the appliances is then

$$E_h = \sum_{a=1}^{N} E_{h,a} \quad (2)$$

Therefore, a single household electrical power demand for all its appliances for a single day can be expressed as:

$$E_T = \sum_{a=1}^{N} \sum_{h=1}^{24} E_{h,a} \quad (3)$$

As mentioned the house is fitted with a rooftop photovoltaic and wind energy source. However, we consider that the electricity demand of the house cannot be fully supported by this system. Therefore, the household must be connected to the main utility grid for additional backup power.

Considering that the hourly energy production of a single PV module in kW is given by:

$$E_{PV,h}, \forall h \in \{1, \ldots .24\} \quad (4)$$

The total daily energy supply from a PV system installed by the user is therefore

$$E_{PV} = \sum_{h=1}^{24} \quad (5)$$

Due to the intermittent nature of PV production, a forecasting device has been installed in the household to provide expected hourly energy predictions. The consumers use this information to schedule their appliances and to anticipate the energy prices. The energy forecasts are also submitted to the utility company so as to determine the additional power to be allocated to the house and to generate electricity tariffs for the households. We assume that the energy supplier has different feed in tariff structures for different households and depend on their energy and production capacity. However customers pay the same tariff for each unit of grid imported power. In this study single house load is taken, every single house consists of several micro generators, heat buffers, local controllers etc. Various numbers of houses are joined together into a micro grid, swapping electricity and information between the houses. The aim of the energy management system is to propose a universal solution for distinct future domestic machineries and configuration of houses, the system should be flexible and generic since multiple objectives are possible and the purview of the system may differ in future. The concept of energy management is validated and it is shown in fig.3-5,

Validation using labview:

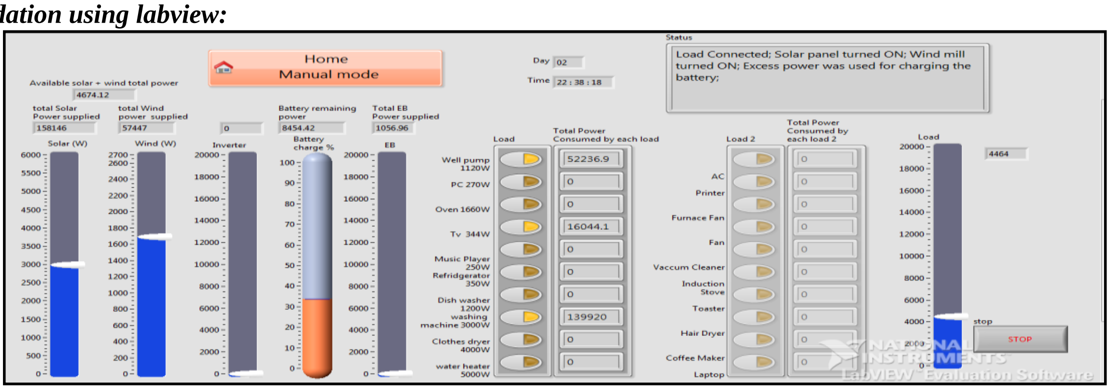

Fig. 3: Validation with both wind and PV partial supply.

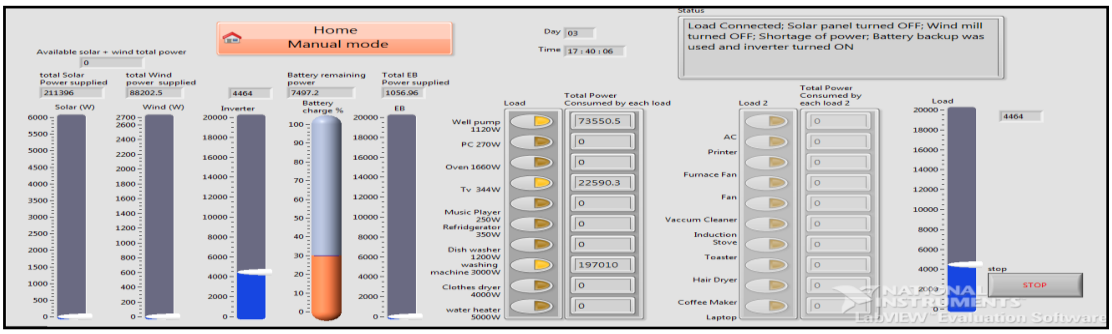

Fig. 4: Validation with battery supply.

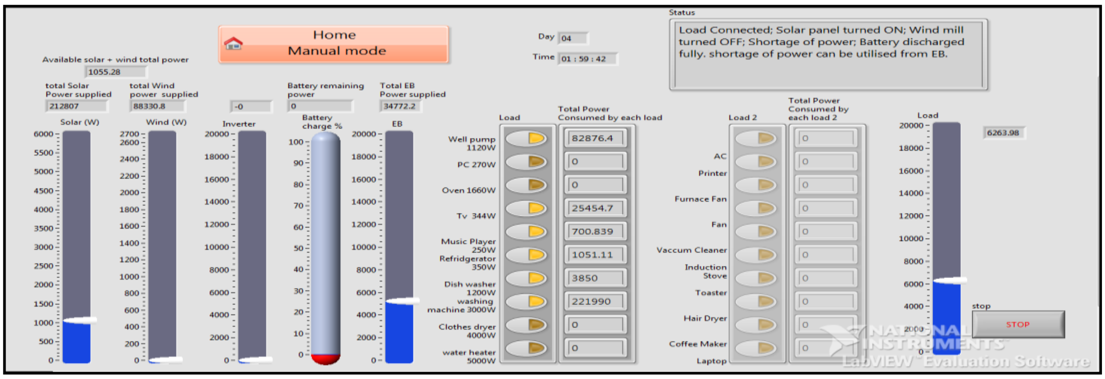

Fig. 5: Validation with grid supply.

Table 1: Insolation and wind speed for the months January 2014 to December 2014.

S.No	Month	Wind Speed	Solar insolation in (kWh/m^2/day)
1	Jan	5.68	5.07
2	Feb	6.35	5.84
3	Mar	6.16	6.5
4	Apr	2.38	6.08
5	May	4.51	5.85
6	Jun	7.88	4.85
7	Jul	9.48	4.50
8	Aug	10.19	4.64
9	Sep	9.27	4.99
10	Oct	8.83	4.45
11	Nov	6.67	4.22
12	Dec	4.47	4.46

Validation using real time insolation and wind speed in labview:

Information in Table 1 is used for forecasting of wind and solar energy. But there may be changes with the data due to the environmental conditions. Also solar insolation varies with season. It is found from Table 1 that, annual solar radiation is 5.12(kWh/m^2/day) and annual average wind speed is 6.825.

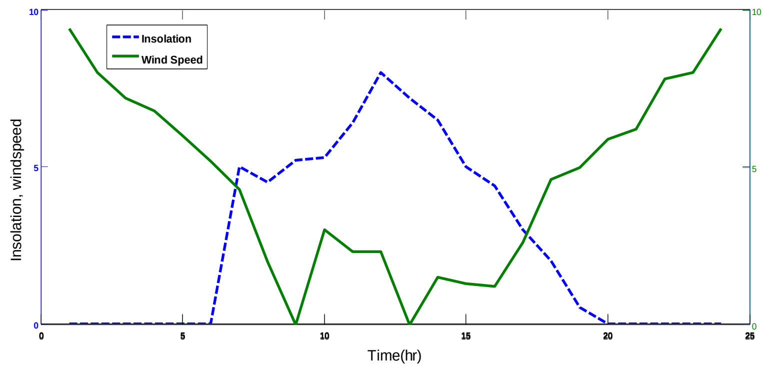

Fig. 6: Solar insolation and wind speed of one day with to time.

The wind speed and the solar insolation is taken into an account, with this data given to the controller the output is calculated. The power output from the wind turbine depends on three main variables:

Size of the turbine, speed of the wind, efficiency of the turbine and generator.

The wind power equation is given as

$$P = \frac{1}{2}\rho A V^3 \quad (6)$$

Where P = power in watts

ρ = air density (kg/m^3)

A = swept area of the turbine blades (m^2)

V = wind speed (m/s)

The turbine power equation is

$$P = \frac{1}{2}\rho A V^3 C_P \quad (7)$$

C_P = power coefficient (unique to each turbine type), $C_{P\ max}$ = 0.59 (from Betz' Law)

Cost analysis of various loads used for corroboration:

Table 2: Load scheduling with cost analysis in Indian Rupees

S.No	Appliances	Capacity	Usage /Day (hours)	Units consumed per day	Units consumed per year	Cost in Rupees
1	Well pump	373 - 1119	1	0.373 - 1.119	136 - 408	224 - 1054
2	PC	40 – 270	8	0.32 - 2.2	117 - 803	196 - 4120
3	Microwave oven	600-1700	2	1.2 - 3.4	438 - 1241	1144 - 6832
4	TV	150-475	5	0.75 - 2.4	274 - 876	652 - 4602
5	Iron *	1000-1800	0.5	0.5 - 0.9	182.5 - 329	295 - 817
6	Refrigerator	350 - 550	24	8.4 - 13.2	3066 - 4818	1,956 - 30,619
7	Dish washer	1200-1500	1	1.2 - 1.5	438 - 548	1,144 - 2,437
8	Washing machine	500-3000	1	0.5 - 3	183 - 1095	295 - 6,047
9	Clothes dryer	300 - 4000	1.5	0.45 - 6	164 - 2190	266 - 13,274
10	Water heater	4000-5000	0.5	2 - 2.5	730 - 913	3,638 - 4,846
11	Room AC	1000 - 5000	10	10 - 50	3650 - 18250	22,910 - 1,19,270
12	Printer	200-400	1	0.2 - 0.4	73 - 146	93 - 239
13	Furnace fan	200-300	4	0.8 - 1.2	292 - 438	706 - 1,144
14	Fan	50 – 175	8	0.4 - 1.4	146 - 511	239 - 2,193
15	Vacuum cleaner	500-1200	1	0.5 - 1.2	183 - 438	295 - 1,144
16	Induction stove	600-3200	2	1.2 - 6.4	438 - 2336	1,144 - 14,238
17	Toaster	800-1500	0.5	0.4 - 0.75	146 - 274	239 - 652
18	Hair dryer	1000-1875	0.3	0.3 - 0.6	110 - 219	185 - 487
19	Coffee maker	800-1500	0.5	0.4 - 0.75	146 - 174	239 - 281
20	Laptop	50-150	8	0.4 - 1.2	146 - 438	239 - 1,144
Total					11058.5 - 36445	36,099 - 2,15,440

Annual solar energy output:

Electricity generated in output of a PV system is

$$E = A^* r^*H^*PR \quad (8)$$

E = Energy (kWh)
A = Total solar panel area (m^2)
r = Solar panel yield (%)
H = Annual average solar radiation on tilted panels
PR = performance ratio, coefficient for losses

The installation cost of solar and wind is given below:

Wind = Rs.3, 00, 000; Solar = Rs.7, 08, 575; Total = Rs.10, 08, 575.

Installed capacity of wind and solar is

Wind = 2.7kW;Solar = 6kW;Total = 8.7kW.

Approximately 30.3 – 100 units are consumer per day in this case. According to LT tariff in Indian Rupees (Bi-Monthly, Based on the Slab Rates in TamilNadu, India with Effect From 01/04/2012, valid upto 11/12/2014) the total cost of energy consumed is Rs.36,099 – Rs.2,15,440 (app). Table 2 shows the cost of energy in Rupees for various appliances. Hence the payback period is minimum of 4 years. But the life time of the micro grid is 20 years. It is clear that for better efficiency devices which exploit full potential of the micro grid is to be used. We are interested in developing an efficient energy management for a cooperative network of interconnected micro grids, which are supplied by different sources of energy renewable energy. One of the key challenges of such energy management task is to deal with the intermittent nature of the renewable energy resources in a cost-efficient manner. In fact, if proper cooperation among the inter-connected micro grid is performed then one can potentially exploit the energy exchange process among the micro grid to minimize the amount of purchased energy from the main grid and/or to avoid producing energy by using expensive power generators. In other word, cooperation among micro grid can enable us to mitigate the intermittent nature of renewable energy, which can translate into significant cost saving compared to the case where operation of micro grid is optimized separately. This is especially important for the heterogeneous network of micro grid where the available amount of energy from wind and solar power sources can be quite different over a 24-hour period (i.e., there is no solar power during night time while there is usually more wind power over night).

In Fig 7. Appliances are scheduled for optimal use of the energy. The chart is drawn by taking time (in hours) in x-axis and solar insolation with wind speed in y-axis. The output power is predicated and the loads are scheduled according to their usage and their power consumption.

Demand response is defined as an end user's ability to reduce their electric load in response to price signals or other grid management incentives and regulations. Demand response has been used in the power industry for decades, but recently, advances in communications and control technologies are greatly expanding demand response capabilities allowing it to be used as a capacity and energy resource. Demand response provides much-needed flexibility to the power system.

Conclusion:

The proposed optimization framework for energy management in micro grids seems to have better performance. The uncertainties in power demand, wind/solar power generation are considered in our proposed system model. It is found that an efficient Domotics controller in a micro grid would be able to exploit local available renewable energy to supply its local power demand, to efficiently charge/discharge its storage facility, and to sell back surplus energy to the main grid during high-priced electricity period.

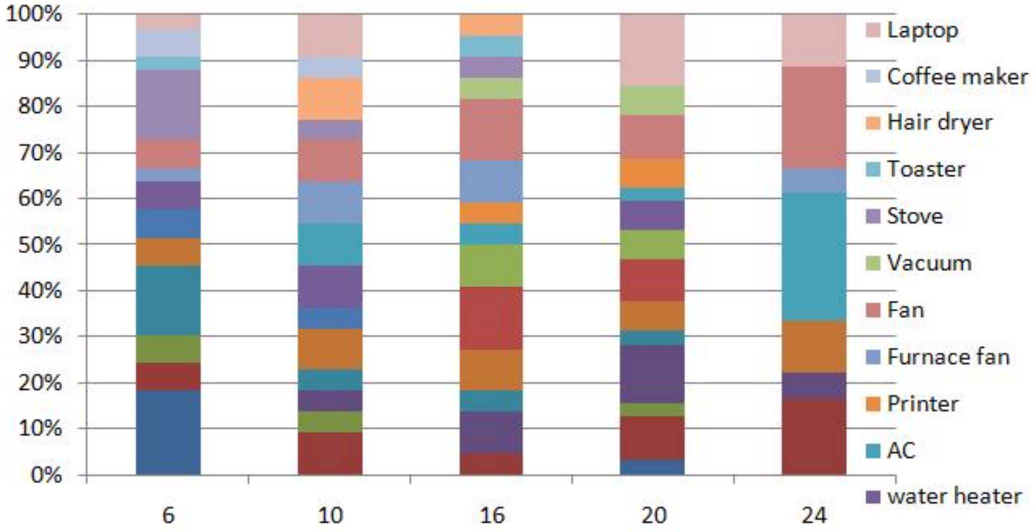

Fig. 7: Optimal Prediction of load schedule.

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