Scheduling the Generation of Renewable Power Sources

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Abstract: In the energy management of the islanded operation of small power system, the economic scheduling of the generation units is a crucial problem. Applying right timing the performance of the supply can be maximized. The optimal operation of a wind turbine, a solar unit, a fuel cell and an accumulator is searched by a linear programming tool. The method is in its test phase in the microgrid model at Budapest Tech's Renewable Energy Park.

Keywords: Renewable energy, scheduling, constraint programming

1 Introduction

Keeping the balance between load and generation is the basic rule of all power systems. In the autonomous supply systems, as space crafts, airplanes or small islands the critical amount of fuel, the specific schedule of the generation capability gives the scheduling problem special importance.

In the power system the daily load curve can be well forecasted. The forecast is based on statistical, analytical or technological models.

Characteristics of the system elements:

Load:

> The power system contains controlled and uncontrolled loads. The time curve can be well forecasted.

Generator:

> The generators have many constraints that are minimal/maximal capacity, fuel amount (total generated energy), speedup ratio.

Storage:

> Large amount of electricity cannot be stored economically. Only small systems use super condensers and batteries, the greater systems contain pumped water storage, pressurized air, hydrogen generator, etc. The storage units have double characteristics: these are loads with limited capabilities, and later they may turn into generators. Due to the losses of transformation the storage has never 100% efficiency.

The scheduling problem exists in any power system. In the autonomous islanded renewable power systems and in the isolated microgrids for the limited power source the dynamic portfolio management is really important.

2 The Microgrid

We investigate a small renewable system that has a wind turbine, photovoltaic panels and a fuel cell. The test system is implemented at the roof of the Budapest Tech.

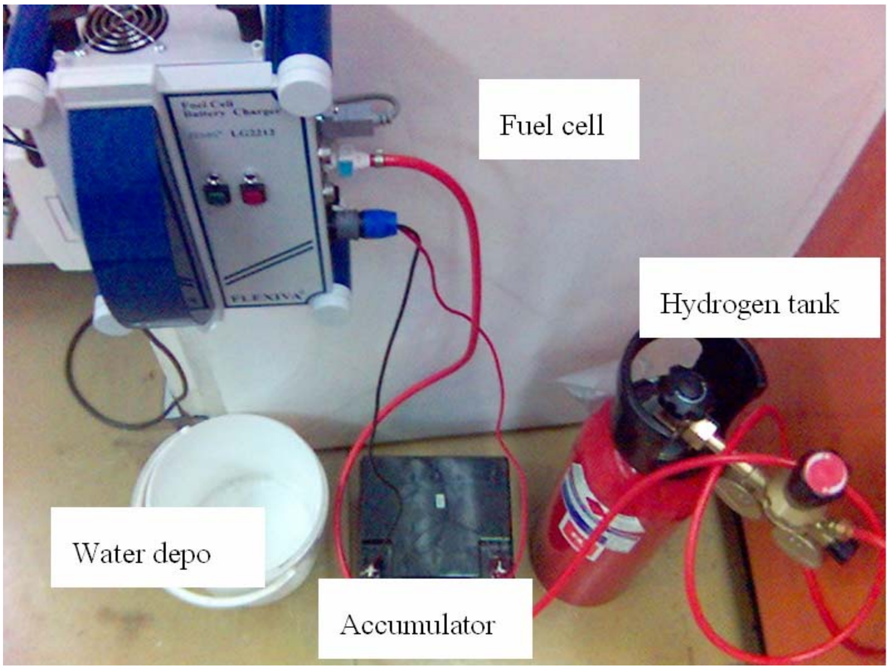


Figure 1
The Fuel Cell

Figure 2
Wind turbine

Figure3
Photovoltaic panels

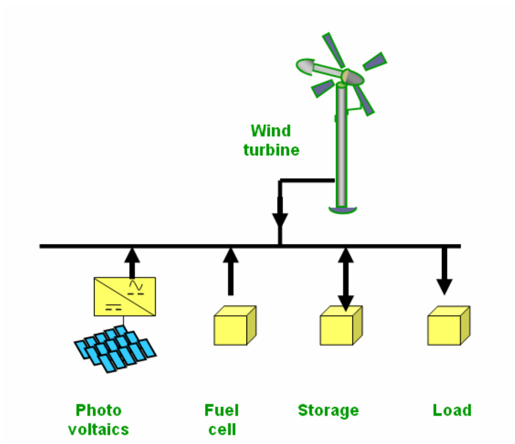


Figure 4
The islanded renewable system

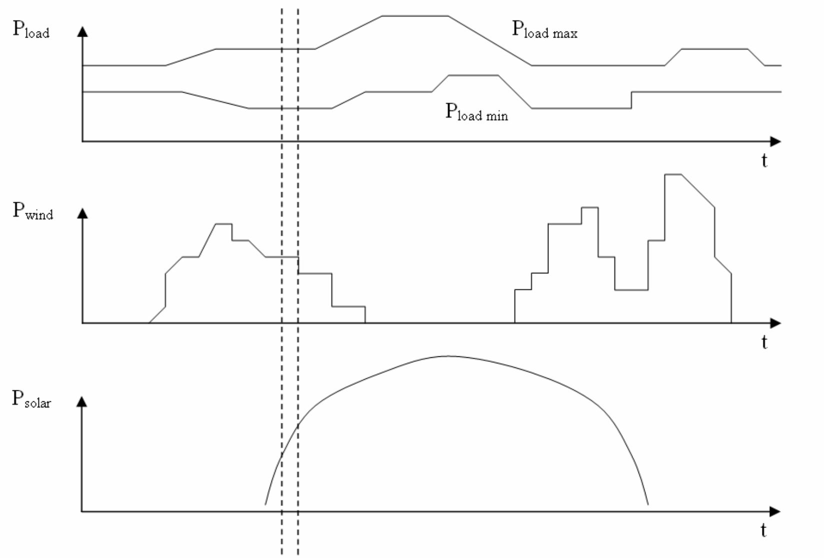
The wind power generation strongly depends on the weather. The generation capability can be estimated 24 hours in advance. This generation has priority above the others.

The photovoltaic generation can be well forecasted, too, but it depends on the coverage factor of the sky.

The fuel cell has limited output for a long time, but the total generated energy is determined by the amount of the hydrogen fuel.

Most of the loads can be controlled between limits (this is the DSM - demand side management). Typical load and generation curves (wind, solar, storage and fuel cell) are shown on Fig. 5.

Fitting the generation composition to the actual load is a Tetris[1] problem, where a load curve must be composed by the power of different generator units – at each moment. The applied priorities are: 1st - wind, 2nd – photovoltaics, 3rd - Fuel cell (if it is necessary). The surplus energy is used for charging the storage capacity (accumulator). The different units have difference costs, as well. The wind and solar energy are 'free', the storage has bad efficiency and limits, the hydrogen based fuel cells are costly and have limited capacity. It is only the emergency reservoir.



[1] Tetris (trademark of The Tetris Company)

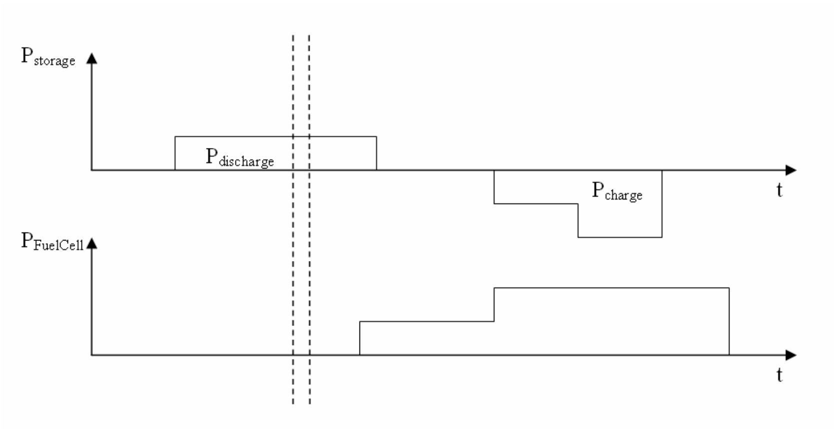


Figure 5
The load limits and the different generation curves

This continuous constrained portfolio problem is solved by twodimensional linear programming. In the daily schedule the demand and generator curves are sliced for semi steady parts, typically into 5 min. units. In this time window we use the classical linear programming methodologies with constraints.

There are five different operational modes:

1 There is surplus energy to store (see Fig. 6).

2 The primary generation is not enough therefore the accumulator is discharged (only till 40%).

3 In case of lack of primary generation (no wind and/or sun shine) the accumulator and the Fuel Cell come into operation (see Fig. 7).

4 In case of lack of the stored energy only the Fuel Cell comes into operation.

5 In case of unsatisfactory energy generation the load must be shed.

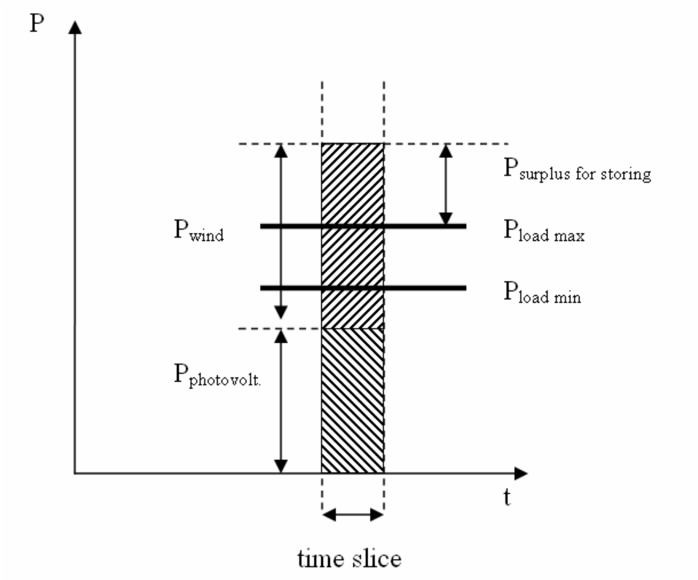


Figure 6
Surplus of primary energy

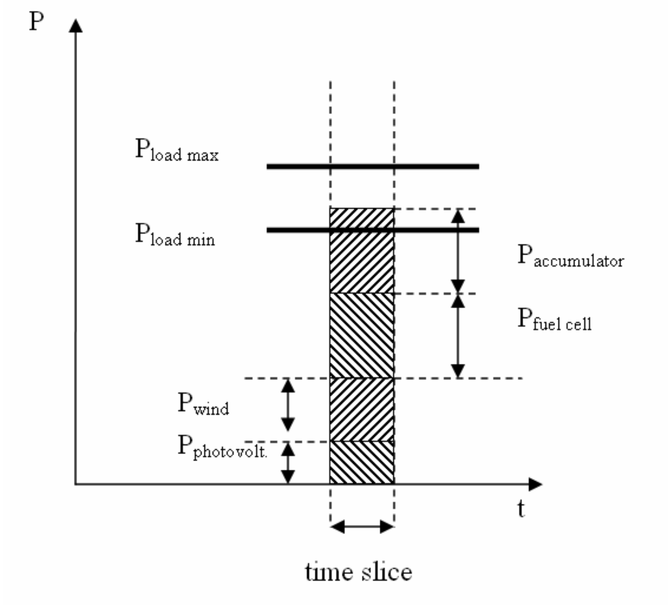


Figure 7
The accumulator and the Fuel Cell are in operation

3 Constraint Programming

The energy controller must distinguish among the above mentioned operational statuses. We set up a set of constraints that helps the linear program to find the optimal solution. We applied the following constraints in the specific case No. 2:

Constraint # 1: Load >= 200 W

Constraint # 2: Load <= 300 W

Constraint # 3: Wind forecast = 110 W

Constraint # 4: Solar forecast = 70 W

Constraint # 5: Fuel Cell maximum capacity = 80 W

Constraint # 6: Storage maximum charging capacity <= 200 W

Constraint # 7:

Load = (Wind + PV + FC) generation + Storage discharging - Storage charging

Constraint # 8: Storage maximal discharging capacity <= 50 W

The LP Problem Constraints are:

# 1)	1 (Load)	+ 0 (Wind)	+ 0 (PV)	+ 0 (FC)	+ 0 (ToStore)	+ 0 (FromStore)	>= 200
# 2)	1 (Load)	+ 0 (Wind)	+ 0 (PV)	+ 0 (FC)	+ 0 (ToStore)	+ 0 (FromStore)	<= 300
# 3)	0 (Load)	+ 1 (Wind)	+ 0 (PV)	+ 0 (FC)	+ 0 (ToStore)	+ 0 (FromStore)	= 110
# 4)	0 (Load)	+ 0 (Wind)	+ 1 (PV)	+ 0 (FC)	+ 0 (ToStore)	+ 0 (FromStore)	= 70
# 5)	0 (Load)	+ 0 (Wind)	+ 0 (PV)	+ 1 (FC)	+ 0 (ToStore)	+ 0 (FromStore)	<= 80
# 6)	0 (Load)	+ 0 (Wind)	+ 0 (PV)	+ 0 (FC)	+ 1 (ToStore)	+ 0 (FromStore)	<= 200
# 7)	-1 (Load)	+ 1 (Wind)	+ 1 (PV)	+ 1 (FC)	- 1 (ToStore)	+ 1 (FromStore)	= 0
# 8)	0 (Load)	+ 0 (Wind)	+ 0 (PV)	+ 0 (FC)	+ 0 (ToStore)	+ 1 (FromStore)	<= 50

Figure 8
Constraints table

We assigned costs to the production of each type of generators:

Wind	1 cent/W
Solar	1 cent/W
Fuel Cell	10 cents/W
Storage charge	-1 cents/W
Storage discharge	3 cents/W

The objective function of the liner program is to find the least cost.

Minimize:

Value = 0 (Load) + 1 (Wind) + 1 (PV) + 10 (FC) - 1 (ToStore) + 3 (FromStore)

Linear program seeks for appropriate values for all variables that fits to all constraints and the objective function is minimal. Table I. shows the different values for the above mentioned 5 operational modes. Let us emphasize that we use the same constraint structure to all the different cases.

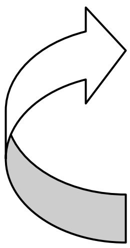
In case of perfect cost dimensioning, the objective function expresses the real cost of the operation.

	1	*2*	*3*	*4*	*5*
	To_Store	*From_Store*	*FC_From_Store*	*FC_Out_ of_Store*	*Overload*
Load	200	200	200	200	270
Wind	125	110	75	110	110
PV	100	70	50	70	70
FC	0	0	25	20	80
ToStore	25	0	0	0	
FromStore	0	20	50	0	
OBJ FUN	200	240	525	380	no solution

Table I

Solution of the operational modes

The continuous operation can be calculated in cycles. The calculation cycle:



- Calculation of load balance in the actual time slice
- Calculation of the status of the storage device and amount of non renewable fuel
- Setting up new constraints
- Calculation of next slice

For linear programming the Archer Tool Company’s (ATP) Linear Programming Tool (LPT) V1.11 was used.

Conclusion

In this paper we made a demonstration of how one can find the optimal schedule for the islanded system with renewable generation. In further studies we plan to automate the step-by-step calculation.

References

[1] Herbert Ferenc: Magyarország első folyamatosan hálózatra termelő mini naperőműve (Elektrotechnika, 2004. 7-8. 232-233 old.) in Hungarian

[2] Sütő Roland: A napelem cellák vizsgálatának kutatási eredményei (Elektrotechnika, 2006. 2.; 8-9 old.) in Hungarian

[3] Dr. Péter Kádár: Energy on the Roof *3rd Romanian-Hungarian Joint Symposium on Applied Computational Intelligence* Timisoara, Romania, May 25-26, 2006; SACI Proceedings pp. 343-352