Analysis of PV/Wind systems by integer linear programming with Neutrosophic numbers by taking into account intermittency of energy production

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Abstract

In a recent paper, we discussed possible use of quadruple Neutrosophic Numbers in order to expand the definition of statistical standard deviation in uncertainty modeling of various engineering systems and elsewhere. In the meantime, in literature there are many discussions on linear programming for various cases, there is only few discussion to take into account the uncertainties involved in the power production of PV/Wind system. In this paper, we consider integer linear programming by considering bi-level values as suggested by Pramanik and Pratim Dey. The purpose of this study is to show that it is possible to consider uncertainties in energy production in the linear programming model.

Introduction

Hybrid renewable energetic systems are systems that integrate more than one renewable energy sources. As they are time, environment and site dependant, one expects that their judicious and complementary combination may overcome some limitations which are inherent to every individual system used alone. Hybrid systems may also reduce the need for energy storage which is very costly and space consuming.[1]

In real cases, sometimes it is of need to consider integrating renewable energy sources in order to build up economical hybrid energetic systems in the case where each type of energy are only available as specific units. For instance, we may need to combine photovoltaic panels and wind turbines with specific capacities to meet an energetic demand in a specific site with a lowest cost. Therefore, determining the optimal energy to be installed leads of determining the number of units from each source. This problem is formulated as an integer linear programming where the objective function to be minimized is the initial capital investment and where the decision variables are the numbers of units which should be pure integer numbers.

While this problem has been discussed in Zaatri and Allab [1], there is only few discussion in the literature on how to take into account the uncertainties involved in the power production of PV/Wind system. As it is known, PV and Wind energy production involves a certain level of intermittency, which makes the power production rather uncertain.

In a recent paper, we discussed possible use of quadruple Neutrosophic Numbers in order to expand the definition of statistical standard deviation in uncertainty modeling of various engineering systems and elsewhere [8]. It is known, that intermittency, intermittence, irregularity, unregularity, uncertainty are part of Indeterminacy, which is in between: interruption and non-interruption. Therefore we can express an expanded model statistical standard deviation to include the notion of intermittency, as follows:

$$X = x' \pm \sigma . k = x' \pm \sigma (\mathrm{T} + \mathrm{I} + \mathrm{F}),$$

Where T,I,F each represents truth value, indeterminacy, and falsehood. That is one of possible interpretations of quadruple Neutrosophic Numbers in the sense of expanded standard deviation, see for instance [8-10].

In this paper, we consider integer linear programming by considering bi-level values as suggested by Pramanik and Pratim Dey [3]. The purpose of this study is to show that it is possible to consider uncertainties in energy production in the linear programming model. So the results will be expressed in upper bound and lower bound limits.

Basics of Linear Programming

Linear programming deals with problems such as maximising profits, minimising costs or ensuring you make the best use of available resources. From an applications perspective, mathematical (and therefore, linear) programming is an optimisation tool, which allows the rationalisation of many managerial and/or technological decisions. An important factor for the applicability of the mathematical programming methodology in various contexts, is the computational difficulty of the analytical models. With the advent of modern computing technology, effective and efficient algorithmic procedures can provide a systematic and fast solution to these models.

A Linear Programming problem is a special case of a Mathematical Programming problem. From an analytical perspective, a mathematical program tries to identify an extreme (i.e., minimum or maximum) point of a function, which furthermore satisfies a set of constraints. Linear programming is the specialisation of mathematical programming to the case where both, function f, called the objective function, and the problem constraints are linear. Mathematical (and therefore, linear) programming is an optimisation tool, which allows the rationalisation of many managerial and/or technological decisions required by contemporary applications. An important factor for the applicability of the mathematical programming methodology in various contexts, is the computational tractability of the resulting analytical models.

Discussion on the problem in question

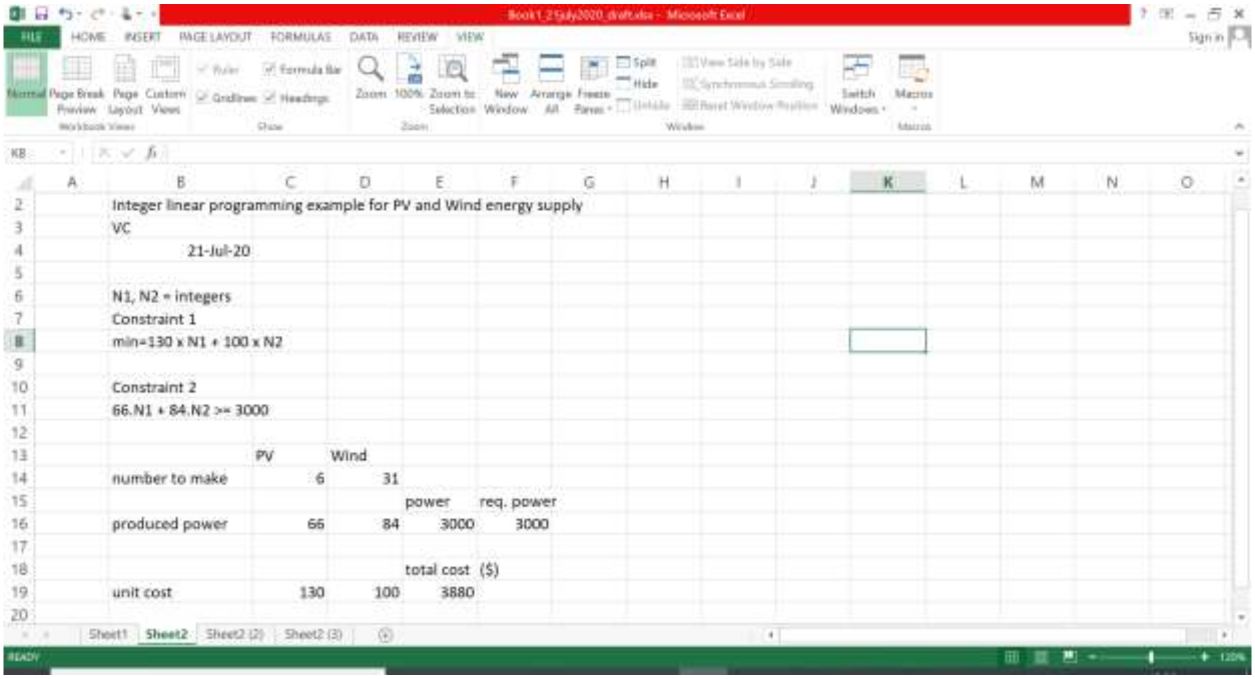
In this paper, we consider the same scenario of estimates of annual power production by PV and wind systems as discussed by Zaatri and Allab [1].

The two equations of constraints in integer linear programming can be expressed as follows [1]:

N1, N2 = integers
Constraint 1
min=130 x N1 + 100 x
N2

Constraint 2
66.N1 + 84.N2 >= 3000

This problem can be solved using MS Excel (goal seek/solver), and the result is shown in the following table 1.



	B	C	D	E	F
2	Integer linear programming example for PV and Wind energy supply				
3	VC				
4	21-Jul-20				
5					
6	N1, N2 = integers				
7	Constraint 1				
8	min=130 x N1 + 100 x N2				
9					
10	Constraint 2				
11	66.N1 + 84.N2 >= 3000				
12					
13		PV	Wind		
14	number to make	6	31		
15				power	req. power
16	produced power	66	84	3000	3000
17					
18				total cost ($)	
19	unit cost	130	100	3880	
20					

Table 1. Result of goal seek (MS Excel) for integer linear programming

The result is : it is found that optimal number of PV cells is 6, and 31 wind systems. And the total cost is found to be $3880.

It is known, that intermittency, intermittence, irregularity, unregularity, uncertainty are part of Indeterminacy, which is in between: interruption and non-interruption. Therefore we can express an expanded model statistical standard deviation to include the notion of intermittency, as follows:

$$X = x' \pm \sigma.k = x' \pm \sigma(\mathrm{T}+\mathrm{I}+\mathrm{F}),$$

Where T,I,F each represents truth value, indeterminacy, and falsehood. That is one of possible interpretations of quadruple Neutrosophic Numbers in the sense of expanded standard deviation, see for instance [8-10].

Now, by simplifying procedures in Pramanik & Pratim Dey [3], we can include uncertainty parameters due to intermittency/indeterminacy of energy production by PV/wind systems, so we will include an extension:

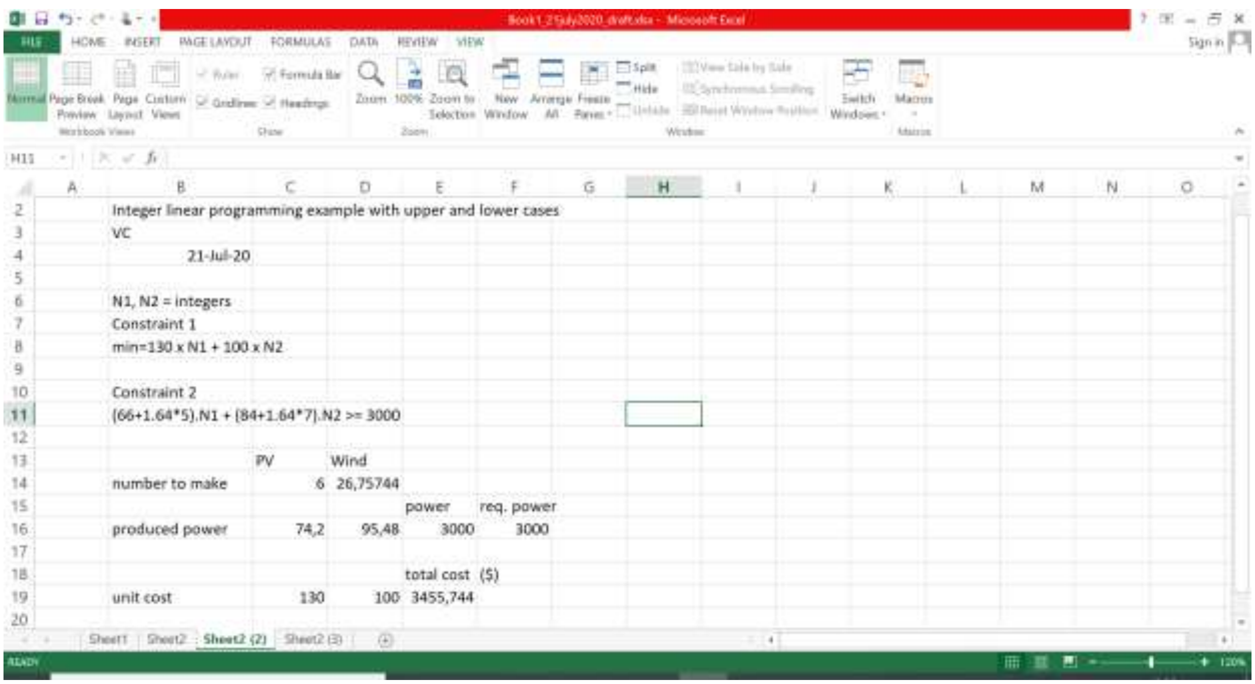
a. Upper bound limit:

(66+1.64*5).N1 + (84+1.64*7).N2 >= 3000

Which comes from setting X = x’ + σ.k

Where we take for simplicity: σ=1.64, k = 5 for PV systems, and k=7 for wind systems. Actual values of k should be determined by observations.

The result is shown in table 2 as follows:



	B	C	D	E	F
2	Integer linear programming example with upper and lower cases				
3	VC				
4	21-Jul-20				
5					
6	N1, N2 = integers				
7	Constraint 1				
8	min=130 x N1 + 100 x N2				
9					
10	Constraint 2				
11	(66+1.64*5).N1 + (84+1.64*7).N2 >= 3000				
12					
13		PV	Wind		
14	number to make	6	26,75744		
15				power	req. power
16	produced power	74,2	95,48	3000	3000
17					
18				total cost ($)	
19	unit cost	130	100	3455,744	

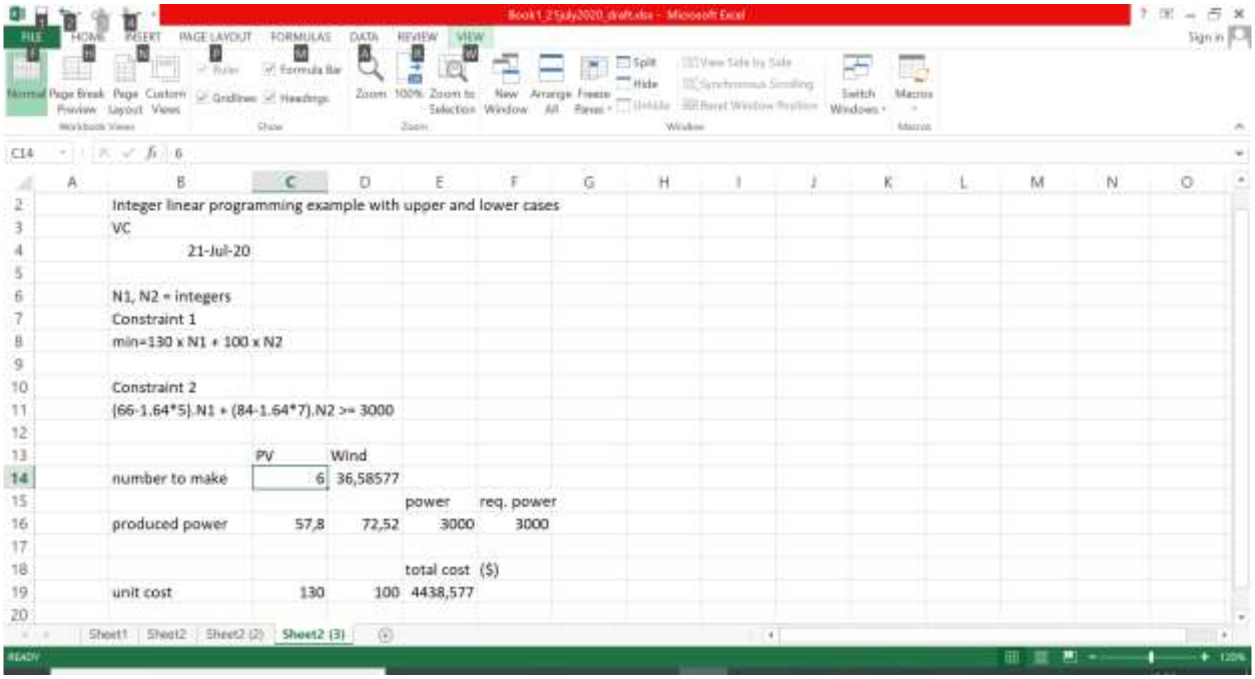
Table 2. Integer linear programming with uncertainties taken into account (upper bound limit).

The result is : it is found that optimal value is 6 PV sets, and 27 wind systems. The total cost is found to be: $3455.74

a. Lower bound limit:

(66-1.64*5).N1 + (84-1.64*7).N2 >= 3000

The result is as shown in table 3.



	A	B	C	D	E	F
2		Integer linear programming example with upper and lower cases				
3		VC				
4		21-Jul-20				
5						
6		N1, N2 = integers				
7		Constraint 1				
8		min=130 x N1 + 100 x N2				
9						
10		Constraint 2				
11		(66-1.64*5).N1 + (84-1.64*7).N2 >= 3000				
12						
13			PV	Wind		
14		number to make	6	36,58577		
15					power	req. power
16		produced power	57,8	72,52	3000	3000
17						
18					total cost ($)	
19		unit cost	130	100	4438,577	
20						

Table 3. Integer linear programming for lower bound limit.

The result is : it is found that optimal value is 6 PV sets, and 37 wind systems. The total cost is found to be: $4438.58.

Therefore we conclude, by taking into account uncertainties due to intermittency of power production of PV/Wind systems, we come up with slightly different optimal values.

For other papers discussing MCDM/linear programming in renewable energy considerations, see [2, 4-7].

Concluding remark

In this paper, by simplifying procedures in Pramanik & Pratim Dey [3], we can include uncertainty parameters due to intermittency of energy production by PV/wind systems, we will include an extension:

$(66+1.64*5).N1 + (84+1.64*7).N2 >= 3000$, which comes from setting $X = x' + \sigma.k$.

Where we take for simplicity: $\sigma=1.64$, $k = 5$ for PV systems, and $k=7$ for wind systems. Actual values of k should be determined by observations.

Similarly, we can consider the lower bound limit by setting:

$(66-1.64*5).N1 + (84-1.64*7).N2 >= 3000$, which comes from setting $X = x' - \sigma.k$.

Therefore we conclude, by taking into account uncertainties due to intermittency of power production of PV/Wind systems, we come up with a slightly different optimal values. Provided we set the PV systems to be 6, we obtain upper bound number of Wind energy system to be 27, and the lower bound number is 37.

This is where the subject of Neutrosophic Logic can be considered. Further investigation is recommended.

VC & FS

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