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A Dynamic Power System Economic Dispatch Enhancement by Wind Integration Considering Ramping Constraint -Application to Algerian Power System

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Abstract- This paper presents a new study of enhancement the dynamic power economic dispatch considering ramping effect. In recent years, the integration of wind power increasingly extends into the electricity grid; this renewable energy source helps remarkably in the production of electrical energy in several points. As known the power demand variation needs economic dispatch at each time period which is a subject to constraints such as the ramp effect which induces a money losses and less power availability, in this study we will see the wind turbine integration impact on this ramping effect. The results give a good enhancement of total production cost and power availability.

Keywords Wind energy, Economic dispatch, Ramping rate, optimization, power system.

1. Introduction

Wind energy has become the friend of man when it comes to have an electric production without environmental pollution, which during today's world tends to this technology because it is a free energy and uses wind to make us electricity that the electricity demand continues to increase along the different call of the environments preservation organization means increasingly.

In this sense in economic terms this energy is still considered expensive compared to the power that it will provide, but even this fact depreciation in a year, because it is a free source of energy or rather has a very low cost compared to traditional central.

In Algeria, the first attempt to connect the turbines to the electricity distribution network was in 1957, with the installation of a 100 kW wind turbine on the site of the Great Winds (Algiers). Designed by the French engineer ANDREAU, this prototype was originally installed in St-Alban England. These two blades of pneumatic variable pitch 30 m high with a diameter of 25 m was bought by “Electricity and Gas of Algeria” and then dismantled and installed in Algeria. [1]

Currently, the total installed wind power in Algeria is insignificant. However, a first wind farm of 10 MW of power has been based in Adrar and has been operational in 2012. In addition, the Ministry of Energy and Mines has projected in its Renewable Energy Development Program, install seven wind farms with a total capacity of 260 MW in the medium term [2], reaching 1,700 MW [3] in 2030. The program also plans to launch the industrialization of certain elements or components of wind turbines, such as blades.

In the same context of protecting the environment and the electricity production at lower cost, there is the cost optimization of traditional central generation, what we call "the economic dispatch of power plants," Mathematically the problem must be reported briefly. It was an objective function FT equal to the total cost to supply a given load. The problem is to minimize the FT subject to the constraint (the sum of the power generated must equal the load with transmission losses included).

The integration of wind power into the electricity grid has effects on the mean static or dynamic level, in this study we will consider wind turbine as an energy source which depends on a daily wind curve and with less cost than traditional power plants. So we will take a scenario for analyzing the impact of the integration of wind turbine on the dynamic economic dispatch, taking into consideration the constraint of the ramp effect of the electric power plants.

2. Economic dispatch problem

The basic economic dispatch problem can described mathematically as a minimization of problem [4-5].

$$Minimize\sum_{i=1}^{ng} F_i(P_i) \qquad (1)$$

Fi (Pi) is the fuel cost equation of the ‘i’th plant. It is the variation of fuel cost ($) with generated power (MW).Normally it is expressed as quadratic equation.

$$F_i\ (P_i) = a_i\ P_i^2\ + b_i\ P_i\ + c_i \qquad (2)$$

If ai >0 then the quadratic fuel cost function is monotonic. The total fuel cost is to be minimized subject to the following constraints.

$$\sum_{i=1}^{ng} P_i = D + P_l \qquad (3)$$

$$P_L = \sum_{i=1}^{ng}\sum_{j=1}^{ng} P_{Gi}B_{ij}P_{Gj} + \sum_{i=1}^{ng} B_{0i}P_{Gi} + B_{00} \qquad (4)$$

$$P_{i\min} \le P_i \le P_{i\max} \qquad (5)$$

Where

D : The real power load

P_i : The real power output at generator bus i

B_{ij},B_{0j},B_{00}: the B-coefficient of Network

P_i^{min} : The minimal real power output at generator i

P_i^{max} : The maximal real power output at generator i

P_L : The network losses

F_i : The cost function of the generator i

ng : The number of generators

By lagrangian multipliers method and Kuhn tucker conditions and the following conditions for optimality can be obtained

$$2a_iP_i + b_i = \lambda\left(1 - B_{i0} - 2\sum_{j=1}^{ng} B_{ij}P_i\right) \qquad (i=1,2,....n) \qquad (6)$$

The non linear equations and inequalities are solved by the following procedure.

1. To initialize the procedure allocate lower limit of each plant as generation, evaluate the transmission loss and incremental loss coefficients and update the demand.

$$P_i=P_{min}, \quad x_i = 1 - B_{i0} - 2\sum_{j=1}^{ng} B_{ij}P_i\ , \quad D_{new} = D + P_l^{old}$$

2. Substitute the incremental cost coefficients and solve the set of linear equations to determine the incremental fuel cost.

$$\lambda = \frac{\sum_{i}^{ng} \frac{b_i}{2a_i}}{D^{new} + \sum_{i}^{n} \frac{x_i}{2a_i}} \qquad (7)$$

3. Determine the power allocation of each plant

$$P_i^{new} = \frac{\lambda - \frac{b_i}{x_i}}{2\frac{a_i}{x_i}} \qquad (8)$$

If plant violates its limits it should be fixed to that limit and the remaining plants only should be considered for next iteration.

4. Check for convergence

$$\left|\sum_{i=1}^{ng} P_i - D^{new} - P_l\right| \le \varepsilon \qquad (9)$$

3. Dynamic Economic Dispatch

Dynamic economic dispatch is an extension of the conventional economic dispatch problem, Since the Dynamic economic dispatch (DED) problem is a challenging operational task in modern power system operation, the optimization method[6] is applied to solve the DED problem. Because of the ramping rate limits, the DED problem is a non-smooth, non-convex optimization problem. The DED problem minimizes the total production cost function associated to dispatchable units[7-10].

The ramping rate limits constraint can be introduced by the following equation

$$-\zeta_i^{down} \le P_i^t - P_i^{t-1} \le \zeta_i^{up} \qquad (10)$$

where ζ_i^{down} and ζ_i^{up} are the ramping down and ramping up rate limit for the *i*-th thermal unit, respectively .

4. Wind energy

The power recovered by a wind turbine can be written in the form [11]:

$$P_W = \frac{1}{2} C_p.\rho.\pi.R_p^2.V_W^3 \tag{11}$$

Where *CP*, is the aerodynamic coefficient of turbine power (it characterizes the aptitude of the aero-generator to collect wind power), ρ is the air density, *Rp* the rotor radius and V_W wind speed. The power coefficient value C_P, depends on the rotation speed of turbine and wind speed.

From fig.1 we notice a large area of great potential for renewable energy, mostly around ADRAR.

In this work we will calculate directly the power delivered by the wind turbine in each time and give the curve of wind turbine power.

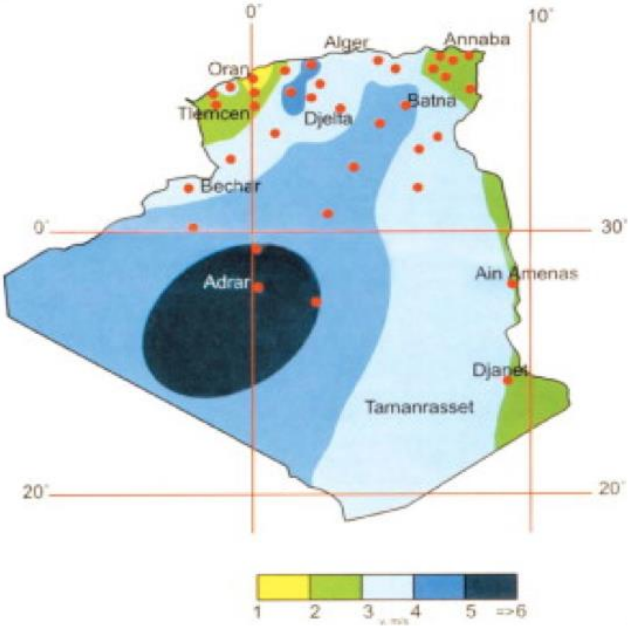


Fig. 1. Wind resource assessment in Algeria [12]

Table 2. Characteristics of the 9 unit Algerian power system

	N° gen	P_{min}/MW	P_{max}/MW	*c*	*b*	*a*	ζ^{down}(MW)	ζ^{up}(MW)
P_{G4}	4	135	1350	0.0085	1.5000	0	100	200
P_{G5}	5	135	1350	0.0085	1.5000	0	100	200
P_{G11}	11	10	100	0.0170	2.5000	0	50	50
P_{G15}	15	30	300	0.0170	2.5000	0	50	50
P_{G17}	17	135	1350	0.0085	1.5000	0	100	200
P_{G19}	19	34.5	345	0.0170	2.5000	0	100	100
P_{G52}	52	34.5	345	0.0170	2.5000	0	100	100
P_{G22}	22	34.5	345	0.0170	2.5000	0	100	100
P_{G80}	80	34.5	345	0.0170	2.5000	0	100	100
P_{G83}	83	30	300	0.0170	2.5000	0	50	50
P_{G98}	98	30	300	0.0170	2.5000	0	50	50
P_{G100}	100	60	600	0.0030	2.0000	0	50	50
P_{G101}	101	20	200	0.0030	2.0000	0	50	50
P_{G109}	109	10	100	0.0170	2.5000	0	50	50
P_{G111}	111	10	100	0.0170	2.5000	0	50	50

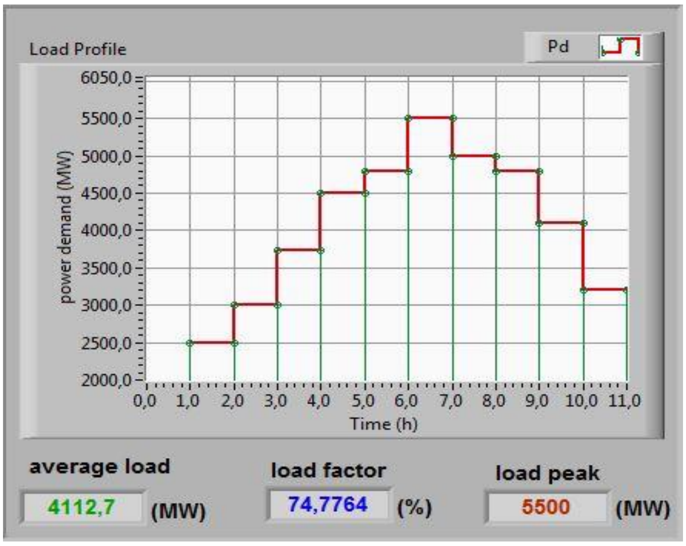
5. Case study and Comments

To assess the efficiency of the wind power plant, it has been applied to dynamic economic dispatch problem with ramping limits constrains of the Algerian 114 bus power plan with 9 classic generators, the total load for 10 time period of the system is given in table 1, the generator data of this system are given in table 2 and the B-coefficient are calculated directly with the power flow results.

Table 1. The total Load for 10 time period

time from (h)	time to (h)	Power Demand (MW)
1	2	2500
2	3	3000
3	4	3727
4	5	4500
5	6	4800
6	7	5500
7	8	5000
8	9	4800
9	10	4100
10	11	3200

We have programmed a simulation program in LabVIEW to perform this computation task, fig.2 present the total load for 10 time period in the graphical interface of the program.



average load 4112,7 (MW)
load factor 74,7764 (%)
load peak 5500 (MW)

Fig. 2. Forecast of total load for 10 time period

5.1. Case study 1:

The dynamic economic dispatch without ramping and without wind turbine is given in table 3

Table 3. The Dynamic economic dispatch for 10 time period without ramping

N° seq	Total Load	Pg_4	Pg_5	Pg_11	Pg_15	Pg_17	Pg_19	Pg_52	Pg_22
1	2500	319,70	236,09	100	98,750	264,656	105,92	104,58	88,63
2	3000	398,15	304,34	100	133,19	340,108	143,95	141,99	115,07
3	3727	517,00	415,11	100	187,27	465,006	206,72	203,41	154,57
4	4500	643,38	535,12	100	244,61	603,780	276,22	270,94	193,20
5	4800	695,02	583,85	100	267,56	663,059	305,66	299,43	208,04
6	5500	867,47	739,23	100	300,00	889,667	345,00	345,00	255,14
7	5000	731,09	617,51	100	283,31	705,723	326,69	319,74	218,09
8	4800	695,02	583,85	100	267,56	663,059	305,66	299,43	208,04
9	4100	577,93	472,76	100	214,96	531,212	239,91	235,72	173,63
10	3200	430,89	334,58	100	148,08	373,913	160,96	158,67	126,27

Pg_80	Pg_83	Pg_98	Pg_100	Pg_101	Pg_109	Pg_111	lambda	Losses	Total Cost
96,326	108,91	557,66	200,00	95,41	98,83	98,83	6,091	58,094	9829,07
134,99	143,86	600,00	200,00	100,00	100,00	100,00	7,453	73,407	13187,94
203,98	198,43	600,00	200,00	100,00	100,00	100,00	9,783	106,362	19442,08
284,19	256,06	600,00	200,00	100,00	100,00	100,00	12,465	162,669	28026,77
300,00	280,83	600,00	200,00	100,00	100,00	100,00	13,651	191,775	31937,11
300,00	300,00	600,00	200,00	100,00	100,00	100,00	18,287	286,523	42816,05
300,00	299,06	600,00	200,00	100,00	100,00	100,00	14,523	214,500	34754,04
300,00	280,83	600,00	200,00	100,00	100,00	100,00	13,651	191,775	31937,11
241,80	226,29	600,00	200,00	100,00	100,00	100,00	11,050	130,827	23325,78
153,35	158,90	600,00	200,00	100,00	100,00	100,00	8,076	80,505	14740,59

After this dynamic economic dispatch without ramping constrains we conclude that the Total cost of all 10 time period is equal to 249996,55$, we note that we have some generator fixed by the max or min limit of power generation like generator 11,98,100,101,109,111 from time 2 to 10.

This time we will run a dynamic economic dispatch with ramping constrains without wind turbine for the 10 time period, the results is shown in table 4.

Table 4. The Dynamic economic dispatch for 10 time period with ramping

N° sequence	total Demand	Pg_4	Pg_5	Pg_11	Pg_15	Pg_17	Pg_19	Pg_52	Pg_22
1	2500	319,70	236,09	100,00	98,750	264,65	105,92	104,58	88,63
2	3000	398,15	304,34	100,00	133,19	340,10	143,95	141,99	115,0
3	3727	523,529	418,526	100,000	183,198	471,445	209,666	206,34	156,02
4	4500	660,896	543,683	100,000	233,198	621,795	284,220	278,89	196,37
5	4800	697,131	585,273	100,000	268,238	666,390	307,172	300,92	208,66
6	5500	877,878	751,548	100,000	300,000	866,390	345,000	345,00	259,41
7	5000	777,878	651,548	100,000	251,374	766,390	297,163	291,03	204,70
8	4800	694,545	583,211	100,000	267,298	666,390	305,094	298,86	207,80
9	4100	594,545	483,211	100,000	217,298	566,390	215,008	211,23	160,72
10	3200	494,545	383,211	76,153	167,298	466,390	115,008	111,23	70,897

Pg_80	Pg_83	Pg_98	Pg_100	Pg_101	Pg_109	Pg_111	lambda	Losses	Total Cost
82,608	96,326	108,917	557,659	200,000	95,413	98,825	6,091	58,094	9829,07
117,71	134,998	143,867	600,000	200,000	100,000	100,000	7,453	73,407	13187,94
185,86	184,998	193,867	600,000	200,000	100,000	100,000	9,913	106,462	19451,52
266,93	234,998	243,867	600,000	200,000	100,000	100,000	12,849	164,858	28094,04
291,28	284,998	283,059	600,000	200,000	100,000	100,000	13,725	193,130	31953,32
345,00	300,000	300,000	600,000	200,000	100,000	100,000	18,706	290,235	42826,18
295,23	300,000	274,713	600,000	200,000	100,000	100,000	13,345	210,036	34905,84
287,92	300,000	280,475	600,000	200,000	100,000	100,000	13,634	191,611	31937,24
199,33	250,000	230,475	600,000	200,000	100,000	100,000	10,077	128,221	23379,78
99,336	200,000	180,475	550,000	200,000	76,463	87,084	5,102	78,094	15404,44

At this dynamic economic dispatch with ramping constrains we conclude that the Total cost of all 10 time period is increased by 972,83 $ and is equal to 250969,38 $, it's normal because the system is more constrained compared to the same system without ramping constrains.

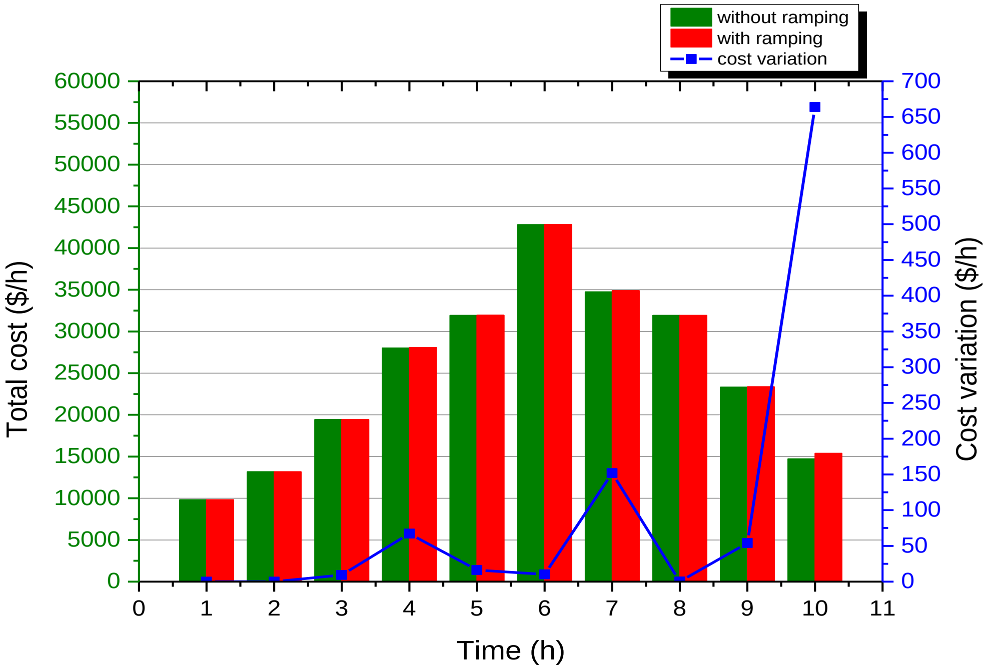


Fig. 3. Cost variation plot of Total cost with ramping and without it

Here we Note in Fig.3 that the system suffers losses of money due to the ramp effect because there was a power deficit caused by this latter in the generators, which should produce more than the ramp effect limited, therefore we have drawn a deficit power curve in terms of time for all the generators see Fig.4.

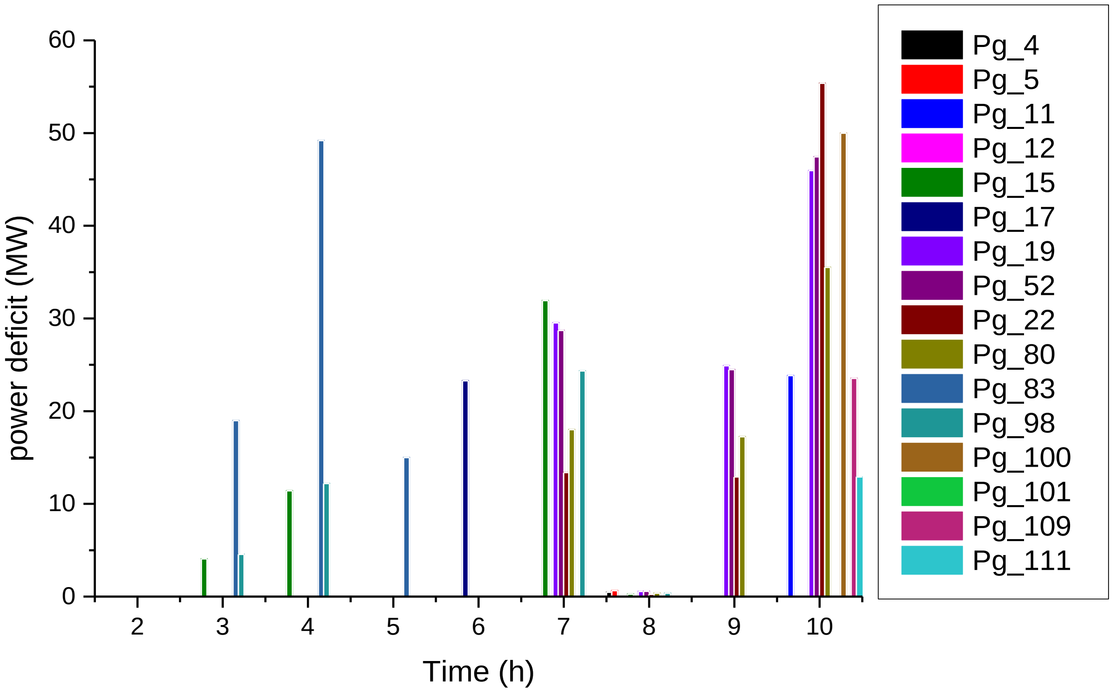


Fig. 4. Power deficit of all generators for 9 time period

The total power deficit is shown in Fig.5, it shows the power that the system of economic dispatch was unable to provide the constraint off of the ramp effect so the system is saturated and it does not work more freely because the power generated in some generators is limited by the limit that the ramp effect required.

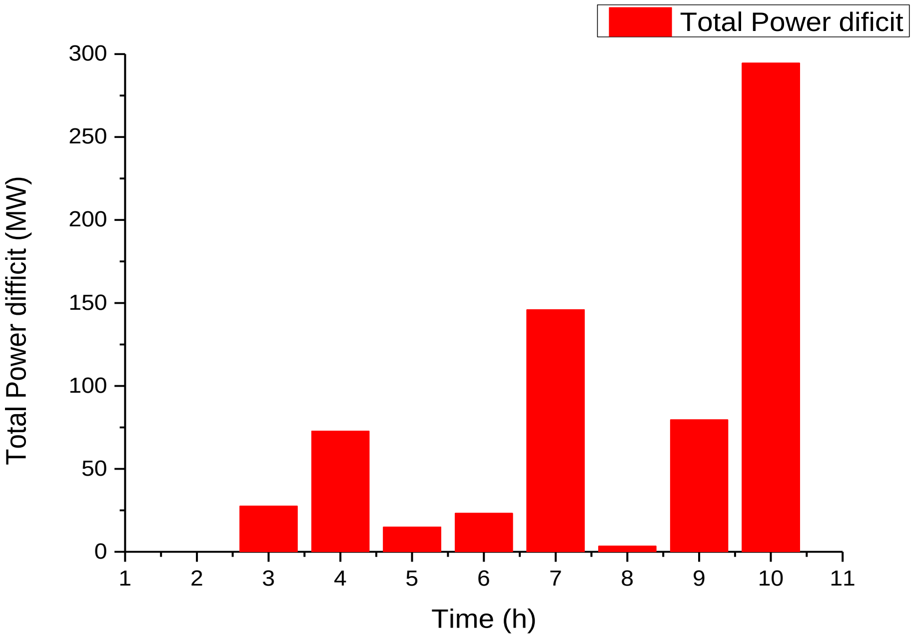


Fig. 5. Total Power deficit of all generators for 9 time period

In this case we will introduce in this system that is until operated by conventional generators, a wind turbine to see the impact of this type of generator on the economic dispatch with the ramp effect.

5.2. Case study 2:

In the previous case we have seen the impact of the ramp effect on the dynamic economic dispatch that cause power deficit and loss of money, we will introduce a wind generator in the power system to see its impact on the cost and the power deficit caused by the ramp effect.

The wind generator that will be used, will be introduced as a cost function, but with a power that is already known or expected, so the generated power has a planned power curve already calculated from a daily wind curve and which will not be affected by the economic dispatch.

We expect to have a wind farm (Table.5) in south west region of Algeria particularly near Adrar operational and generating around 100MW.

Table 5. Caracteristics of the wind generator implemented at bus 12

	N° gen	Pmin/MW	Pmax/MW	c	b	a	ζ down(MW)	ζ up(MW)
P_{G12}	12	0	100	0.002	0	0	100	100

We take a scenario of 10 time period of the power generated by this wind farm situated in the region of Adrar, which is shown in fig.6.

We suppose a wind speed forcast and we make this curve of power generation in MW of all period coresponding to the 10 time load period.

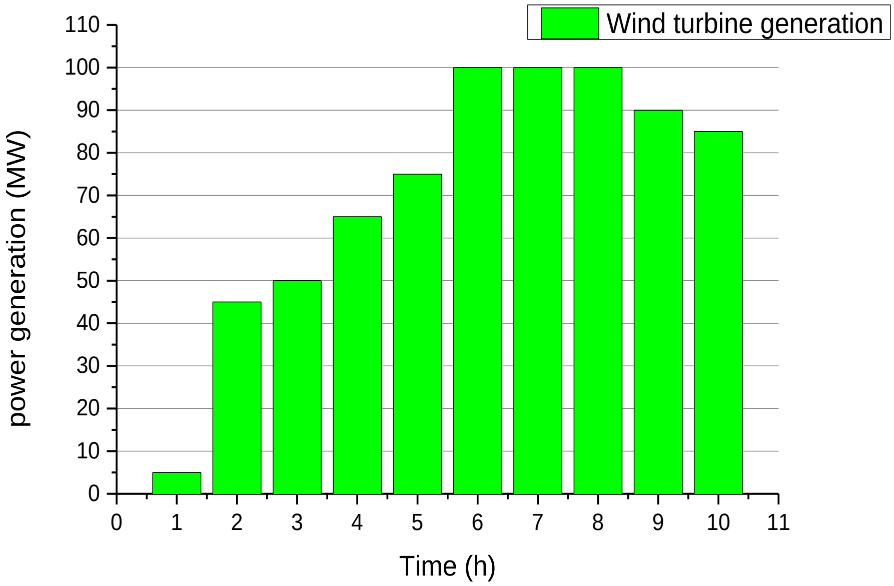


Fig. 6. Forecast of wind power generation

The dynamic economic dispatch without ramping and with wind turbine is given in Table 6.

Table 6. The Dynamic economic dispatch for 10 time period without ramping with wind

Total Demand	Pg_4	Pg_5	Pg_11	Pg_12	Pg_15	Pg_17	Pg_19	Pg_52	Pg_22
2500	318,756	235,114	100	5	98,270	264,077	105,634	104,309	88,430
3000	388,673	293,692	100	45	128,142	333,364	140,613	138,737	112,883
3727	506,044	402,370	100	50	181,347	457,423	202,993	199,806	152,454
4500	628,617	517,559	100	65	236,596	593,895	271,390	266,325	190,848
4800	677,164	562,799	100	75	258,019	650,690	299,670	293,713	205,326
5500	834,177	697,882	100	100	300,000	857,250	345,000	345,000	249,522
5000	707,557	589,544	100	100	270,696	689,735	318,977	312,405	214,754
4800	671,784	556,333	100	100	255,090	647,201	297,984	292,105	204,563
4100	558,490	449,753	100	90	204,372	518,188	233,530	229,587	170,254
3200	413,494	314,704	100	85	138,706	361,810	154,987	152,861	122,486

Pg_80	Pg_83	Pg_98	Pg_100	Pg_101	Pg_109	Pg_111	lambda	Losses	Total cost
82,457	96,150	108,714	556,752	200,000	95,188	98,646	6,079	57,499	9796,07
115,125	132,316	141,563	600,000	200,000	100,000	100,000	7,309	70,107	12845,67
178,948	200,946	196,109	600,000	200,000	100,000	100,000	9,610	101,439	18944,62
251,424	280,185	253,361	600,000	200,000	100,000	100,000	12,223	155,200	27216,81
283,136	300,000	277,195	600,000	200,000	100,000	100,000	13,342	182,712	30929,44
345,000	300,000	300,000	600,000	200,000	100,000	100,000	17,512	273,832	41145,02
306,638	300,000	294,519	600,000	200,000	100,000	100,000	14,112	204,826	33380,29
281,780	300,000	276,245	600,000	200,000	100,000	100,000	13,252	183,085	30644,30
211,742	236,665	222,592	600,000	200,000	100,000	100,000	10,741	125,174	22373,40
130,293	148,624	154,959	600,000	200,000	100,000	100,000	7,812	77,925	14084,62

After this dynamic economic dispatch without ramping constrains and with wind we conclude that the Total cost of all 10 time period is equal to 241360,23 $, the price has clearly decreased compared to the same case without wind .we note that we have some generator fixed by the max or min limit of power generation like generator 11,100,101,109,111 from time 2 to 10.

This time we will run a dynamic economic dispatch with ramping constrains with wind turbine for the 10 time period, the results is shown in table 7.

Table 7. The Dynamic economic dispatch for 10 time period with ramping with wind.

total Demand	Pg_4	Pg_5	Pg_11	Pg_12	Pg_15	Pg_17	Pg_19	Pg_52	Pg_22	Pg_80	Pg_83	Pg_98	Pg_100	Pg_101	Pg_109	Pg_111	lambda	Losses	Total Cost
2500	318,756	235,114	100,000	5	98,270	264,077	105,634	104,309	88,430	82,457	96,150	108,714	556,752	200	95,188	98,646	6,079	57,499	9796,07
3000	388,673	293,692	100,000	45	128,142	333,364	140,613	138,737	112,883	115,125	132,316	141,563	600,000	200	100,000	100,000	7,309	70,107	12845,67
3727	512,337	405,426	100,000	50	178,142	463,654	205,848	202,650	153,873	182,846	182,316	191,563	600,000	200	100,000	100,000	9,736	101,655	18953,56
4500	645,170	524,842	100,000	65	228,142	611,068	279,044	273,926	193,935	262,712	232,316	241,563	600,000	200	100,000	100,000	12,586	157,719	27278,91
4800	679,660	564,469	100,000	75	258,814	654,630	301,464	295,476	206,069	286,655	282,316	279,816	600,000	200	100,000	100,000	13,429	184,368	30945,98
5500	835,353	699,254	100,000	100	300,000	854,630	345,000	345,000	250,011	345,000	300,000	300,000	600,000	200	100,000	100,000	17,558	274,249	41145,15
5000	735,353	599,254	100,000	100	250,516	754,630	296,515	290,452	204,473	293,518	300,000	275,373	600,000	200	100,000	100,000	13,271	200,083	33470,33
4800	670,717	554,898	100,000	100	254,488	654,630	296,725	290,840	204,018	280,947	300,000	275,427	600,000	200	100,000	100,000	13,215	182,690	30644,96
4100	570,717	454,898	100,000	90	204,488	554,630	210,944	207,336	158,403	195,573	250,000	225,427	600,000	200	100,000	100,000	9,875	122,416	22420,54
3200	470,717	354,898	75,764	85	154,488	454,630	110,944	107,336	72,721	95,573	200,000	175,427	550,000	200	78,562	89,299	5,168	75,358	14670,69

At this dynamic economic dispatch with ramping constrains with wind we conclude that the Total cost of all 10 time period is increased by 811,62 $ and is equal to 242171,84 $, it’s normal because the system is more constrained compared to the same system without ramping constrains.

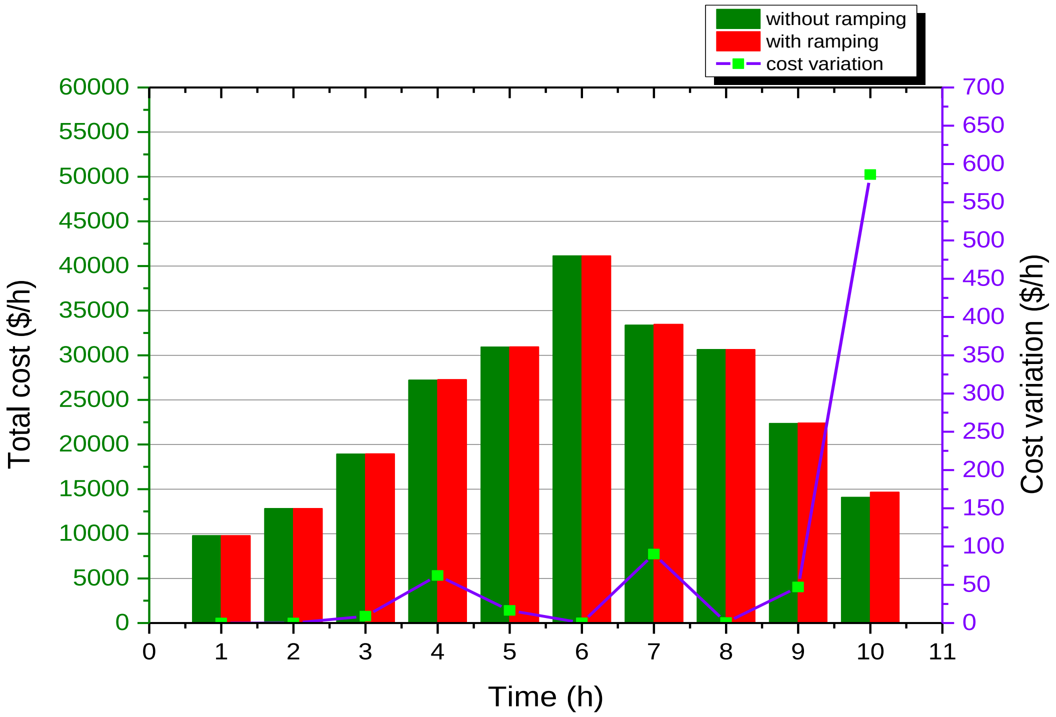


Fig. 7. Cost variation plot of Total cost with ramping and without it at wind integration

As the previous case we see that the system has suffered losses of money due to the ramp effect because there was a power deficit caused by this latter in the generators, which should produce more than the Ramp effect limited, it has drawn a deficit power curve in terms of time for all generators see Fig.8.

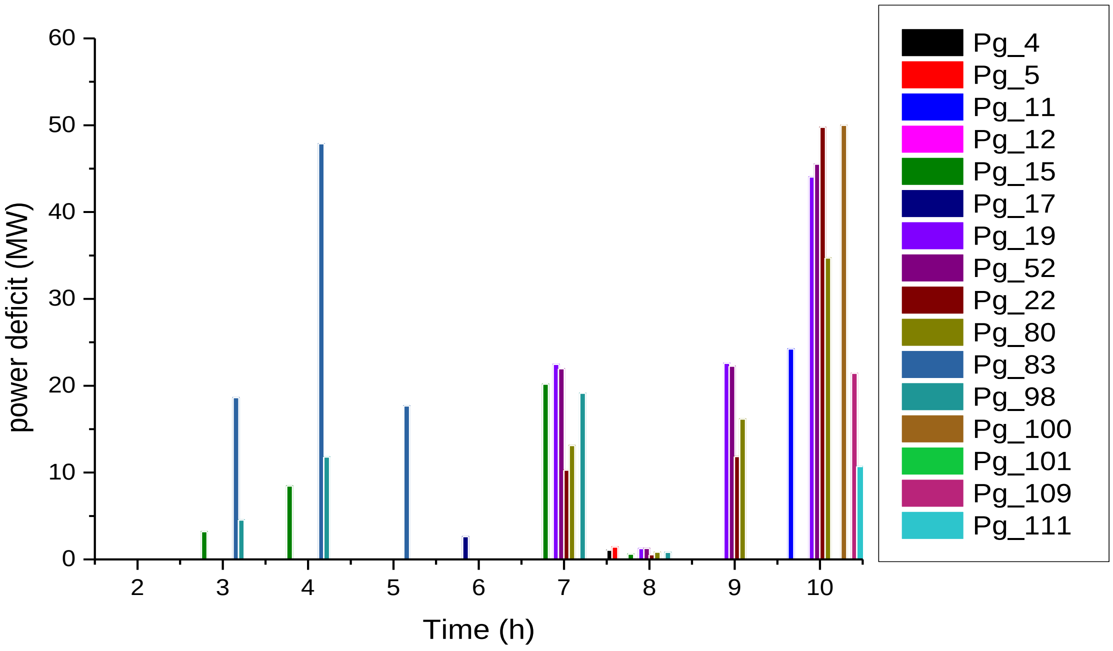


Fig. 8. Power deficit of all generators for 9 time period at wind integration

In this case the total power deficit shown in Fig.9 is reduced compared to the previous case, it shows the power that the system of economic dispatch was unable to provide the constraint off of the ramp effect so the system is saturated and it does not work more freely because the power generated in some generators is limited by the limit that the ramp effect required.

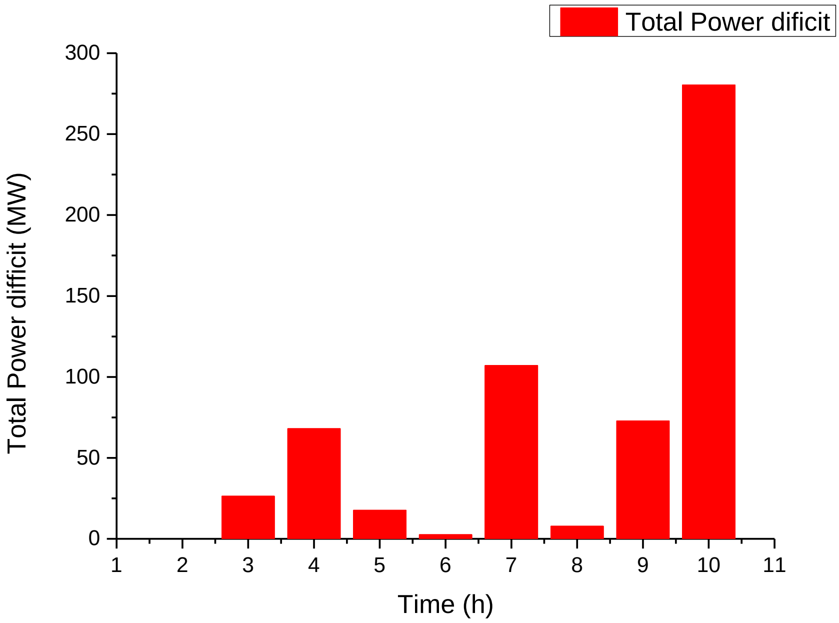


Fig. 9. Total deficit powers for 9 times periods at wind integration

From this case it is clear that wind has improved the system of dynamic economic dispatch with the ramp effect, for this improvement analyzed and deciphered the impact of the integration of a wind turbine in this system we will establish a comparative study.

5.3. Case study 3:

To study the effect of the integration of a wind turbine on the economic dispatching we will realize the comparison between two key points, the total production cost and availability of power or the power deficit.

See Fig.10, which shows the cost variation of production in the case of ramp effect with wind turbine or without it.

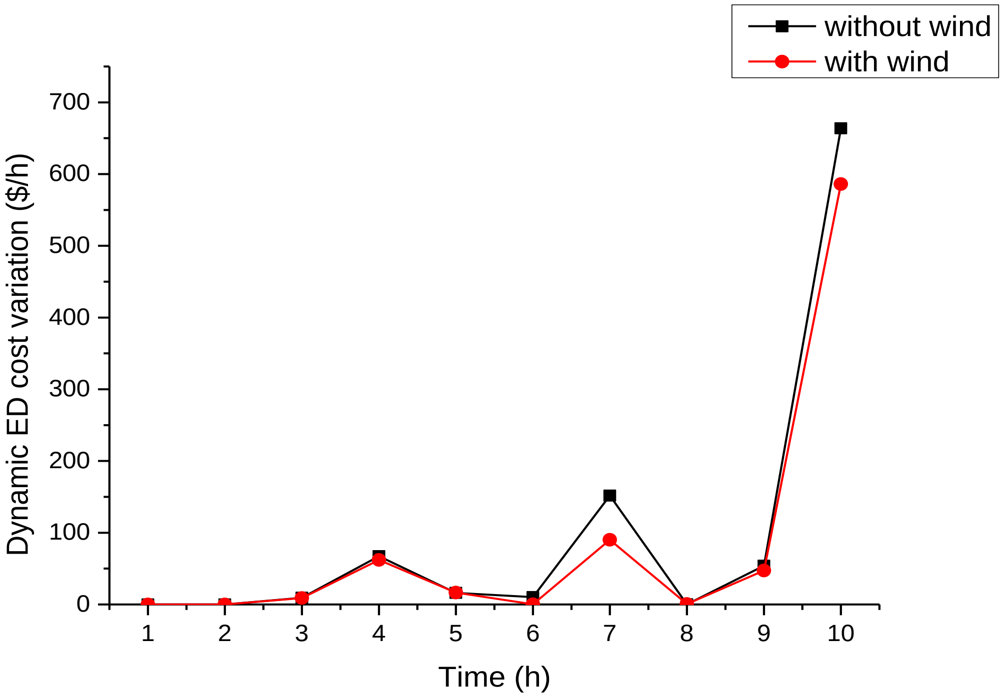


Fig. 10. Cost variation due to ramp effect without and with wind

Table 8. Review of cost improvement in dynamic dispatching economic by integration of wind power

	Total cost ($)	Money loss ($)	Improvement by wind integration ($)
DED without ramping without wind	249996,547	972,83	161,21
DED with ramping without wind	250969,38		
DED without ramping with wind	241360,225	811,62	
DED with ramping with wind	242171,843		

From Table 8 we can clearly notice that the results are positive, the integration of wind turbine in the system of dynamic economic dispatch has improved the cost of a value of 161.21 $ in this example, and this improve can be more positive than this if it has another load or wind curve aspect.

In power view point in Fig.11 it is clearly seen that the system after integration of this type of energy is improved regarding power availability in the power deficit, so the power deficit is less severe than a system without wind.

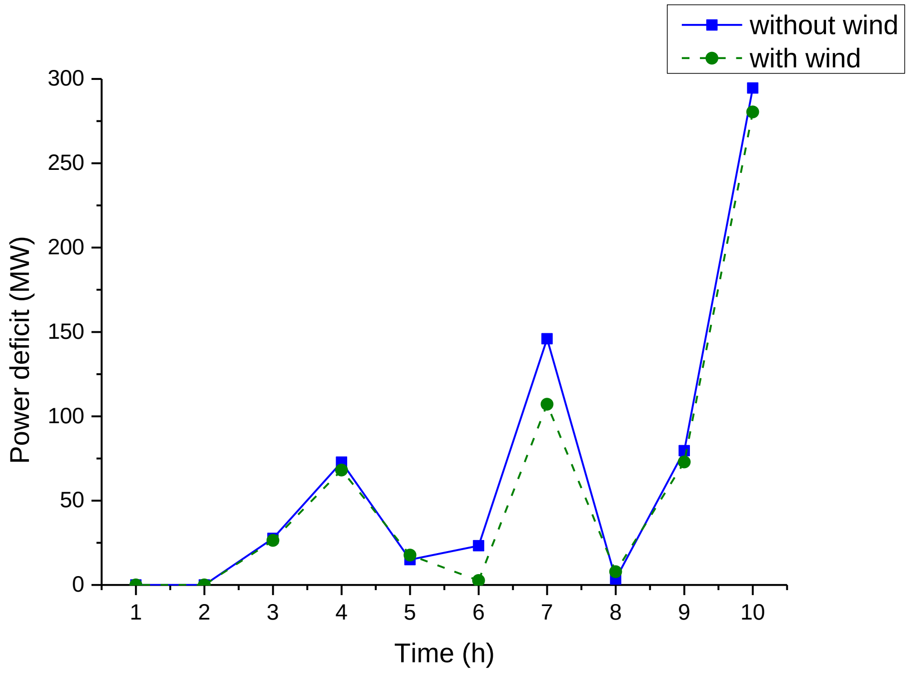


Fig. 11. Power deficit due to ramp effect without and with wind

Table 9. Review of power availability improvement in dynamic dispatching economic by integration of wind power

	Power deficit (MW)	Improvement by wind integration (MW)
DED without ramping without wind	662,289	79,228
DED with ramping without wind		
DED without ramping with wind	583,062	
DED with ramping with wind		

From Table 9 it is observed that the power deficit decreased from a value of 79.2 MW which reflected an improvement over the DED with the ramp effect and a less constrained system.

6. Conclusion

in this study we proved the renewable energy introduction effectiveness, notably wind energy, and its positive impact on the modern power system management, while saving the total production cost and serve more power possible according to the demand, without interruption.

as cited in the paper the ramp effect makes the system less flexible, it reduces power availability to perform the economic dispatch normally, so the power variation in each sequence induces this problem automatically. to minimize this power deficit, we just proved that the integration of wind energy significantly reduces the impact of this constraint that reach the dynamic economic dispatch.

otherwise , each economic dispatch have more constraint, automatically it becomes more expensive, this will make the loss of money compared to the same system without constraint, in this study we proved that the inclusion of the wind turbine reduce greatly the loss of money.

For this, we just have concluded that the integration of wind energy has a positive impact on the dynamic economic dispatch considering ramping constraints, due to the improvements that can make in this system.

References

[1] E.Hau, Wind Turbines, Fundamentals, Technologies, Application, Economics, 2nd ed. Springer, 2005.

[2] Equilibres, La lettre de la Commission de Régulation de l'Electricité et du Gaz, N 12, Mars 2011

[3] Programme des énergies renouvelables et de l'efficacité énergétique, mars 2011

[4] D. P. Kothari. J. S. Dhillon. Power System Optimization, PHI Learning Pvt. Ltd. 2004 .

[5] D. P. Kothari. I. J. Nagrath Tata. Modern power system analysis. McGraw-Hill Education. 2003.

[6] A.J. Wood. B.F. Wollenberg. Power Generation Operation and Control. 2nd Edition, John Wiley & Sons, New York, 1996.

[7] Souag S. Benhamida F. “A Virtual Instrument for Dc Power Flow Solution Using Labview Language“. Advances in Electrical and Electronic Engineering, 2012, 10(02), 2012, pp. 68-74.

[8] Z. L. Gaing, “Particle swarm optimization to solving the economic dispatch considering the generator constraints,” IEEE Trans. on Power Sys., vol. 18, no. 3, pp. 1187-1195, August 2003.

[9] X. Xia and A.M. Elaiw, “Optimal dynamic economic dispatch: a review,” Electr. Power Syst, Res., vol. 80, pp. 975–986, 2010.

[10] Gwo-Ching Liao, “A novel evolutionary algorithm for dynamic economic dispatch with energy saving and emission reduction in power system integrated wind power,” Energy, vol. 36, no. 2, pp. 1018-1029, 2011.

[11] Piwko, R., Osbom, D., Gramlich, R., Jordan, G., Hawkins, D., and Porter, K. . “ Wind energy delivery issues“, IEEE Power & Energy Magazine, November/December, pp. 67-56, 2005.

[12] A. B. Stambouli, “Algerian renewable energy assessment: the challenge of sustainability”, Energy Policy, Vol. 39 (8), pp.4507-4519, 2011.