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Frequency Regulation in Multi Area Power System Optimized By Firefly Swarm Hybridization Algorithm

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Abstract: ***Automatic Generation Control of two area multi unit interconnected thermal power system with dynamic participation of Doubly Fed Induction Generator based on the wind turbines. In this work two areas consisting of three unequal turbines both areas are connected to the DFIG based wind turbine. Area 1 consisting of three reheat turbines with Doubly Fed Induction Generator based on wind turbine and area2 consisting of three non reheat turbines with Doubly Fed Induction Generator based on wind turbine and two areas interconnected by tie line. Two different controllers are used, namely PID and cascaded PD-PI controllers. The controllers effectively tuned by hybridization algorithm. 1% step load disturbance is applied in area 1 for analyzing the dynamic performance. The performance of two area multi-unit power system is done in MATLAB/SIMILINK software. The dynamic response of the considered system is compared in terms of undershoots, overshoot and settling times***

Keywords: ***Automatic Genaration Control(AGC); Proportional Integral Derivative(PID) and cascaded PD-PI controllers; Doubly Fed Induction Generator based wind turbine(DFIG).***

I. INTRODUCTION

Two areas 1 and 2 interconnected by a tie line. The main objectives of AGC are to maintain zero steady state error in frequency deviation and tie line power deviation. There are many control techniques are used to maintain constant frequency. Area1 and area2 are connected by the DFIG with turbine. In this paper wind energy is also considered. Now a day's most of the electrical power is generated using DFIG wind turbines. DFIG is to control the active and reactive power required system operation.

In the literature survey several optimization techniques and control strategies have been proposed in the field of LFC. In LFC of single area thermal power system controlled by the PID and integral controller and optimized by PSO optimization technique [2].

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Liner Quadratic Regulator using load frequency control [3]. Two area two units inter connected power system controlled by PID controller and optimized by DEPSO [4]. AGC interconnected power system controlled by cascaded PD-PID controller optimization technique is GWO [5].Optimized by DE algorithm [6].

Five areas interconnected power system using Firefly algorithm [7]. Interconnected power system and each area attached to PEV using TLBO optimization technique [8].

Automatic generation control of both areas are fixed to DFIG wind turbine controlled by integral controller [9]. Interconnected thermal power system controlled by PIDF controller by TLBO optimization[10].Active frequency control by PD-PI controller using TLBO algorithm [11]. Single area controlled by PD-PI controller by using GWO [12].

To Minimize the ITAE function in area1, applied 1% step load distribution. Both areas are connected to the DFIG wind turbine. Speed controller of different penetration levels are 5%, 20% and 50% and it is observed that lower wind penetration improves steady state performance. The performance of the PID controller and PD-PI controller is studied for different penetration levels. Lower penetrations are best performance as compared to higher penetration levels

Area1 consists of three reheat turbine units and area2 consists of three non reheat turbine units. Hybridization algorithm is implemented for PID and cascaded PD-PI controllers and to know the optimum values of the controllers. Area participation factors are area1 are a11+a12 +a13=1 and area2 are a14+a15+a16=1.Each unit participation factor taken as 0.33.

$$\text{ACE1}=\Delta P_{12}+B_1\Delta f_1 \tag{1}$$

$$\text{ACE2}=\Delta P_{21}+B_2\Delta f \tag{2}$$

Where ΔP_{12} and ΔP_{21} are represents deviation of tie line powers. Two areas connected to wind DFIG. DFIG generate the electrical power in large wind turbine. Wind energy do not participate frequency control because added to doubly fed induction generator is constant output voltage and constant frequency. Two controllers are implemented to thermal power system.

II POWER SYSTEM INVESTIGATED

A. Power system network used in this work

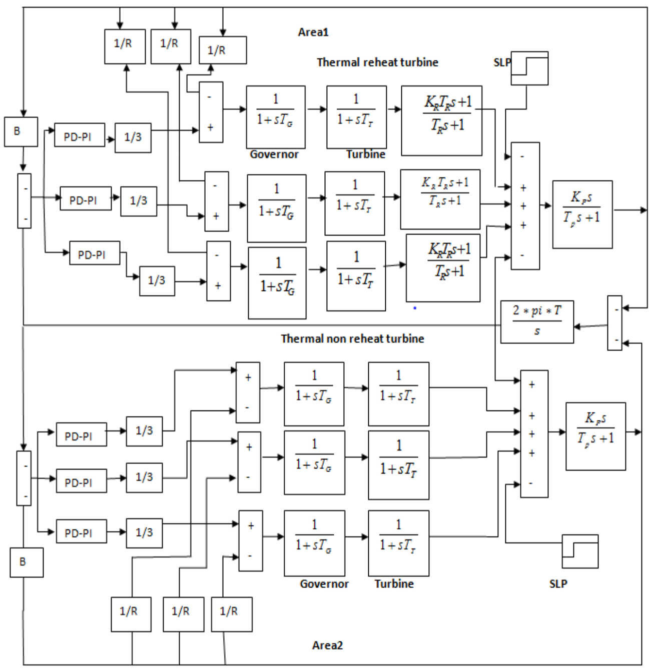

Fig.1 Two area three unit thermal power system

B. Structure of controllers

PID controllers are used in many control applications.PID controllers are used to reduce the overshoot time , undershoot time and settling time are taken less time but PID controllers not satisfactory input signal contains noise and unwanted harmonics. Cascaded PD-PI controller gives better transient response with less settling time. It is combination of two controllers which takes single input and produces single output value. Cascaded PD-PI controller reduces the over shoot, under shoot times and settling time. Cascaded PD-PI controller structure shown in figure2.

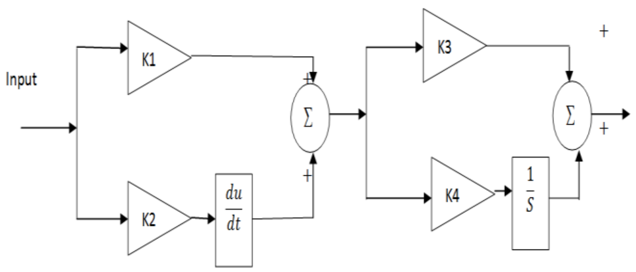

Fig.2 Cascaded controller of PD-PI

III MODELING OF DFIG WIND TURBINE

In general wind energy does not participate in frequency control. So as to maintain the constant frequency DFIG is added to the AGC. DFIG is used to active power to be controlled required by the system operations. DFIG wind turbine active frequency control shown in figure [3]. Additional control signals are considered $\Delta P^{*}f$ is a wind power set point based on the frequency, it produces maximum power.

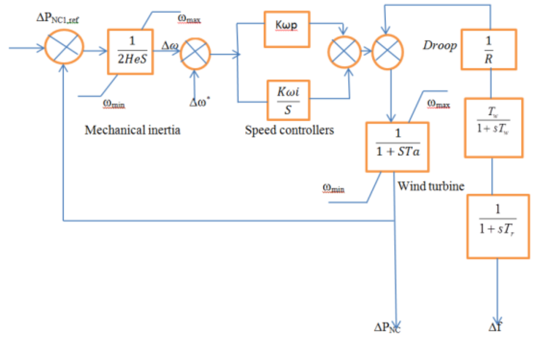

Fig.3 DFIG wind turbine

IV. HYBRIDIZATION OF PSO AND FA (HPSOFA)

Firefly to another firefly is calculated as shown in Eq.3 .

$$r_{ab} = \sqrt{\sum_{k=1}^{d}\left(x_{a,k} - x_{b,k}\right)^2} \tag{3}$$

When ever Light intensity Firefly a is less than the firefly b then a is moved towards b, then update the particle position using Eq.4

$$x_a = x_a + \left[\beta(r)\right]\left(x_b - x_a\right) + \alpha\left(rand\right) \tag{4}$$

Problems in the firefly algorithm overcome with the hybridization of FA with PSO. The velocity equation in PSO is modified by replacing acceleration constants with FAparameters.

$$V_i^{k+1} = wV_i^k + \beta_0 e^{-\gamma r_{ij}^2}\left(Pbest - Z_i\right) + \alpha\left(rand - \frac{1}{2}\right)\left(Gbest - Z_i\right) \tag{5}$$

V ANALYSIS OF RESULTS

Hybridization algorithm used to tune the gains of PID and cascaded PD-PI controllers by considering the ITAE as objective function. The performance of the considered system is analyzed using PID and PD-PI controllers. Frequency deflection in area 1 without DFIG wind turbine are fig. 4 and frequency deflection in area 2 without DFIG wind turbine are shown in fig. 5. Tie line deviation without DFIG wind turbine shown in fig. 6.

$$\text{ITAE} = \int_0^t \left(\left|\Delta f_1\right| + \left|\Delta f_2\right| + \left|\Delta P_{tie}\right|\right).t.dt \tag{6}$$

Two area three units interconnected thermal power system with DFIG wind turbine, both areas connected to the DFIG wind turbine. Three levels of wind penetration i.e. 5%, 20%and 50% are taken into the consideration. It is observed that the lower wind penetration levels shows less settling time and improves the performance. Three levels of wind penetrations applied for the both controllers i.e. PID and cascaded PD-PI controllers. Deviation in area 1 with DFIG wind turbine shown in fig.7 and area2 fig.8 and tie line fig.9 for PID controllers. Cascaded PD-PI controller frequency deviation in area1 with wind turbine shown in fig. 10, and area2 shown in fig.11, and tie line power shown in fig.13. The wind penetration values are shown in table4 [9].

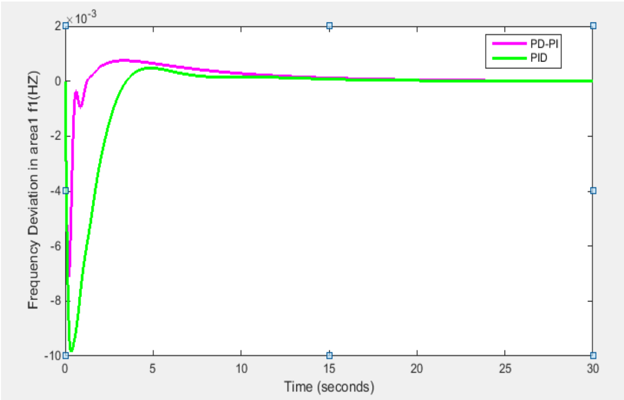

Fig 4.Frequency deviation in area1 without DFIG

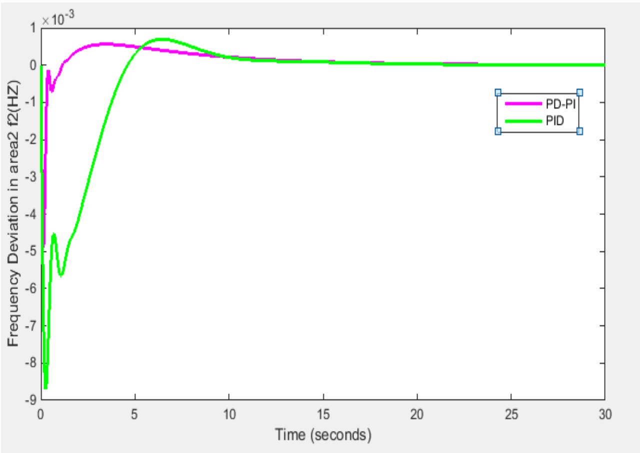

Fig.5.Frequency deviation in area2 without DFIG

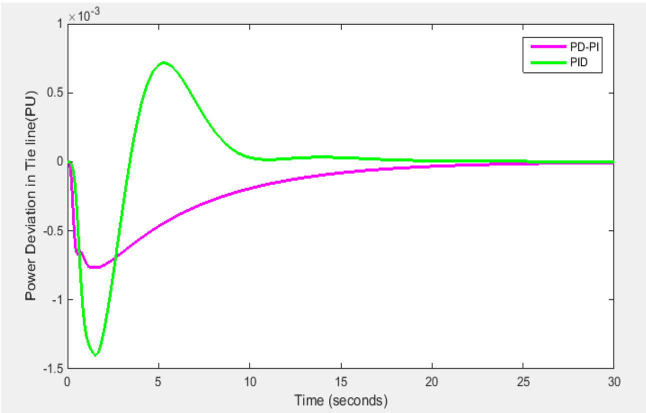

Fig.6.Tieline power deviation without DFIG

TABLE 1 .Peak overshoots (O_{sh}), Peak undershoots (U_{sh}), Settling time (T_s) of different controllers

Controllers		Area1(Δf_1)	Area2(Δf_2)	Tie line(ΔP_{tie})
PID	U_{sh}	-0.0098	-0.0086	-0.0014
	O_{sh}	0.0004	0.0007	0.00071
	T_s	9.32	9.6	13.25
PD-PI	U_{sh}	-0.0071	-0.0049	-0.00076
	O_{sh}	0.0003	0.0005	0.0001
	T_s	2.48	2.68	19.03

A.Frequency deviation with DFIG wind turbine with PID controller.

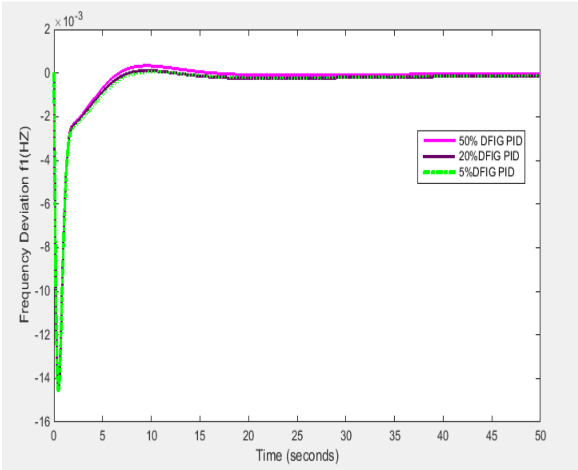

Fig..7 frequency in area 1 with DFIG wind turbine

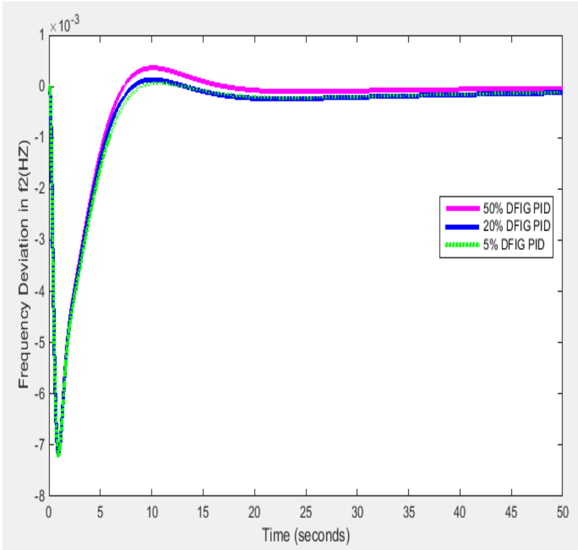

Fig.8 Frequency deviation in area 2 with DFIG wind turbine

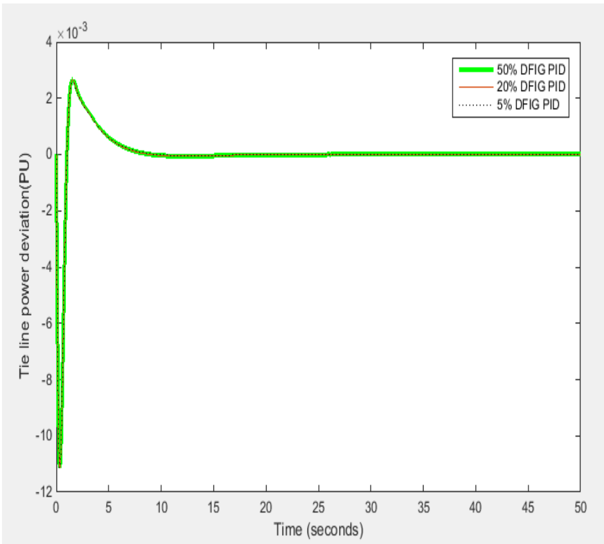

Fig. 9 Tie line power deviation with DFIG wind turbine

TABLE 2. Peak undershoots (U_{sh}), Peak over shoot (O_{sh}), and Settling time (T_s).

Percentage		Δf_1	Δf_2	$\Delta P_{tie\ line}$
5%	U_{sh}	-0.01444	-0.0078	-0.011
	O_{sh}	0.0005	0.00066	0.00026
	T_{sh}	8.68	9.3	8.89
20%	U_{sh}	-0.0017	-0.00719	-0.0110
	O_{sh}	0.0145	0.00013	0.0025
	T_s	9.5	9.85	9.95
50%	U_{sh}	-0.0146	-0.0072	-0.0112
	O_{sh}	0.003325	0.0036	0.00268
	T_s	14.04	14.55	18.55

B.Frequency deviation with DFIG wind turbine with cascaded PD-PI controller.

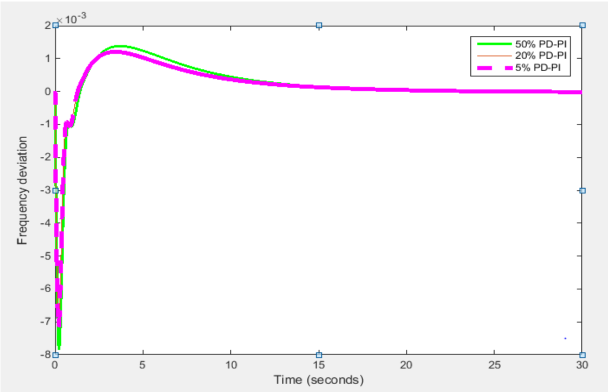

Fig.10 Frequency deviation in area1 with DFIG wind turbine

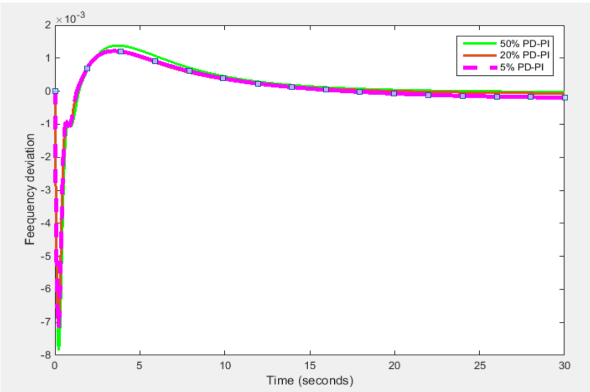

Fig.11Frequency deviation in area2 with DFIG wind turbine.

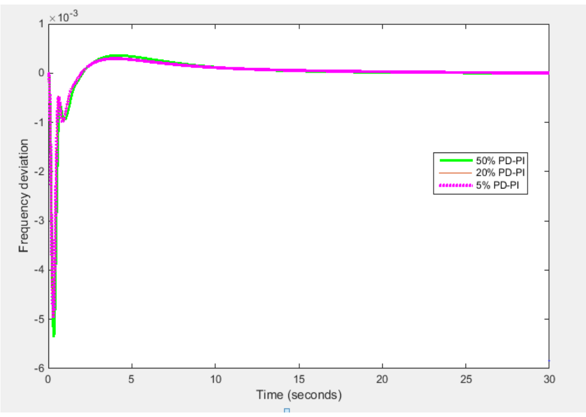

Fig.11Tie line power deviation with DFIG wind turbine.

TABLE 3. Under shoot (U_{sh}), Peak over shoot (O_{sh}), and Settling time (T_s). For cascaded PD-PI controller

Percentage		Δf_1	Δf_2	$\Delta P_{tie\ line}$
5%	U_{sh}	-0.0070	-0.0040	-0.00496
	O_{sh}	0.00012	0.00092	0.000296
	T_s	9.7	9.4	11.4
20%	U_{sh}	-0.0074	-0.0055	-0.00119
	O_{sh}	0.0012	0.00094	0.00035
	T_s	9.8	9.5	11.54
50%	U_{sh}	-0.0073	-0.004	-0.114
	O_{sh}	0.0014	0.00010	0.00036
	T_s	10	9.9	11.6

TABLE 4.Optimum values of speed controller for different DFIG wind turbine penetrations levels

Wind penetration	$K_{\omega p1}$	$K_{\omega i1}$	$K_{\omega p2}$	$K_{\omega i2}$
5%	1.2	0.1	1	0.1
20%	2	0.3	1.98	0.1
50%	1.7	0.2	0.1	1.0

TABLE 5.Optimum gain values of PID controller tuned by Hybridization algorithm.

PID controller	Area1	Area2
K_p	3.7689	3.8548
K_i	2.3458	3.8628
K_d	1.8773	2.9586

TABLE 6.Optimum gain values of cascaded PD-PI tuned by hybridization algorithm.

PI-PD controller	Area1	Area2
K_p	1.7156	0.5565
K_i	1.9989	1.9998
K_p	1.7656	1.9669
K_d	1.9877	0.5586

VI CONCLUSION

The dynamic performance of AGC has been carried out for two-area multi-unit interconnected power system with DFIG, Area1 consists of three reheat turbines and area2 consists of three non-reheat turbine units and both areas interconnected to DFIG wind turbine. 1% step load disturbance is applied in area 1 to study the dynamic performance. Hybridization optimization technique is used for tuning of both controllers. It is observed that Cascaded PD-PI controller is better than PID controller in all aspects. The frequency response is improved by using DFIG wind turbine. The performance of the PID controller and PD-PI controller is also studied for different penetration levels. It is also observed that Lower penetration gives the best performance as compared to higher penetration levels

APPENDIX I

For thermal power system

Parameter	Symbol	Value
Frequency bias factor	B	0.4249
Governor time constant	T_G	0.08
Turbine time constant	T_T	0.3
Re heat time constant	T_R	10
Control area gain	K_P	120
Regulation	R	2.4
Synchronization time constant	T	0.0866
Re heat gain	K_R	0.5
Area participation factors	APF	0.33
Control area time constant	T_p	20

DFIG wind turbine parameters

Parameter	Area1	Area2	Value
Wind turbine inertia	H_{e1}	H_{e2}	3.5
DFIG proportional controller gain	$K_{\omega p1}$	$K_{\omega p2}$	1
DFIG turbine	T_{a1}	T_{a2}	0.2
Transducer time constant	T_{r1}	T_{r2}	15
Wash out filter time constant	$T_{\omega 1}$	$T_{\omega 2}$	6
Regulation	R_1	R_2	2.4

REFERENCES

1. Kundr,Prabha. Power system stability and control. Eds. Neal j. Balu, and Mark G. Lauby Volume 7. New york:McGraw-hill, 1994.
2. G.Pavan kumar,CH.durga prasad “Effect of load parameters variation on AGC of single area thermal power system on presence of integral and PSO-PID controllers’’ 2015 conference on PCCCTSG
3. Radha boruah, Dr.Banikanta Talukdar”Modelling of load frequency control using PI controller and stability determination with linear queadratic regulator’’IOSR-JEEE,2014,pp 30-36.
4. Tridipta kumarpati, binod kumar sahu ‘’Application of hybrid DEPSO algorithm to study the performance of different PID controller structures for Automatic Genaration Control of two area multi units interconnected power system’’, 2014 conference on ICCPCT.
5. Manoj kumar debnath, tarakanta, ranjan kumar mallick”Novel PD-PID cascaded controller for AGC multi-unit interconneted power system optimized by GWO.’’ Confrence on ICPEICES2016.
6. Akashmewara, Girish paramar”Comparision of DE optimized PID controllers for AGCinterconnected power system’’, IEEE confernce 2017..
7. K.jagatheesan,B.ananad “Dsign of Proportional-Integral-Derivative controller for Automatic genaration control of multi area power thermal system Frefly algorithm’’ IEEE journal
8. Mukul dixit, Ranjitroy “Impactof PEVs on Automatic Genaration Control using TLBO’’ IEEE conference on 2015,pp978-1-4799-1823-2.
9. Ibraheem,Khaleequr Rehman niazi and Gulshan sharma”Study on dynamic participation of wind turbines in Automatic Generation Control of power system’’ , 2015,Taylor and Francis ,electric power components and system pp.44-55.
10. Manoj Kumar Debnath, Nimai Charan Patel, Ranjan Kumar Mallick”Automatic Gneration control of two area multi-unit interconnected power system with proportional-integral-derivative controller with PIDF filter optimized by TLBO algorithm’’,2016 ICCPCT.
11. Sidhartha Panda, N.P.Patidar,Mohan Kolhe”Cascaded PD-PI controller for Active power Frequency Control of Two-Area Multi-Units Power System’’, IEEE coference on 2016.
12. sasmita Pandhy,Sidhartha Panda,Mahapatra”A modified GWO technique based cascaded PI-PD controller for AGC Systems in presence of Plug in Electric Vchicles’’,Engineering science and Technology, an journal, internationalVolume20,pp427-442.