International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 10 | Oct -2016 www.irjet.net p-ISSN: 2395-0072

Effect Of POD Controlled Ultra capacitors For Frequency Stability Enhancement By Means Of UFLS Scheme

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Abstract - *This paper presents a complete overview of power and frequency oscillations in power system and the root causes of their generation and how they can be damped. Different Ultra capacitor ratings are taken with with UC and connected to power oscillation damping controller are been presented to reduce these oscillations can be damped efficiently and the importance of selection of stabilizing the power system (PSS). Under frequency load-shedding (UFLS) scheme consider a generation part in securing the system against frequency instability and their execution is utilized as a measure for the upgrade of frequency stability on account of the ultra capacitor (UC). Satisfactory damping of power oscillations is an important issue to be addressed when dealing with the stability of power systems. This phenomenon is well-known and observable especially when a fault occurs. The presented approach solves the effective POD response as selection of the proper feedback to attain frequency stable by means of power system stabilizer.*

***Key Words*: UC - Ultra Capacitor, UFLS - Under Frequency Load Shedding Scheme, PSS - Power System Stabilizer, Frequency Drift, POD - Power Oscillation Damping Controller**

1.INTRODUCTION

Isolated power systems are particularly touchy to generation load uneven characteristics because of their little size. The little size suggests not just that the power systems has less ability to respond to an area load imbalance and that less idleness is available, but additionally that each in-feed exhibits a generous segment of the aggregate interest [1]. Frequency stability of power systems is worried with the capacity of the generation to supply their loads at a frequency inside adequate breaking points after a disturbance [2].

Frequency instability more often than not happens after expansive generation load imbalances. It is essential to keep away from the frequency falling underneath a specific quality, since low frequency may extremely harm power plants and load-side gear and consequently, the power systems integrity [3]. UFLS scheme consider a final resort apparatus to ensure the power systems if there should arise an occurrence of an extreme disturbance [4].

UC's have been proposed to give dynamic power support and the end goal to reduce load-area imbalances [5]. In [6], a UC has been proposed to give frequency control to a stand-alone wind turbine. In [7], a UC has been utilized among others to give frequency control to disconnected power systems with renewable energy sources. This study depends on a streamlined power system model as appeared in Section 2, speaking to key rotor and velocity representative dynamics [8].

2. POWER SYSTEM MODEL

The Fig -1. model recreates the power systems reaction as far as frequency $\Delta\omega$, power generation ΔP_G, and load interest ΔP_D to dynamic power imbalance nature. The i^{th} producing unit is spoken to by a second-arrange model estimate of its turbine-representative systems. Excitation and generators drifters can be ignored for being much quicker than the turbine-governor dynamics. The request of size of the settling time of excitation and generator transients is around 0.6–3 s relaying upon the innovation, while the settling time of turbine-representative systems drifters is around 10–50 s. Here the load-damping variable is set to be zero here.

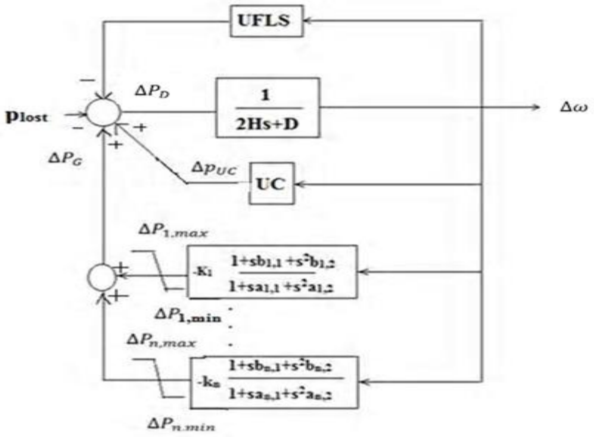

Fig -1: Simplified model of the power system

The addition k_i, and parameters $a_{i,1}, a_{i,2}, b_{i,1}$ and $b_{i,2}$, of the second-arrange model estimation of the ith generating unit can be concluded from more precise models or field tests. Steam turbines can be normally spoken to by first-arrange models as in [9].

3. SIZING OF THE ULTRACAPACITOR

From Fig -1. by first-arrange frameworks and by accepting that force is roughly equivalent to torque in pu,

$$2\,H\Delta\omega^{\cdot} = \Delta p_G - D\,\Delta\omega - \Delta p_D - p_{lost}$$

$$\Delta P_i = -\frac{1}{T_i}(\Delta p_i + k_i\Delta\omega)$$

$$\Delta p_G = \sum_{i=1}^{n} \min\left(\max\left(\Delta pi, \Delta_{pi,\min}\right), \Delta_{pi,max}\right) \qquad .....(1)$$

$$2H\Delta\omega^{\cdot} = -\sum_{i=1}^{n}\Delta p_i - \Delta p_D - p_{lost}$$

$$\Delta p_i^{\cdot} = -\frac{k_i}{T_i}\Delta w. \qquad .....(2)$$

Differentiating (2) yields to

$$2H\Delta\omega^{\cdot\cdot} = -\sum_{i=1}^{n}\frac{K_i}{T_i}\Delta\omega - \Delta p^{\cdot}{}_D - P_{lost}^{\cdot} \qquad .....(3)$$

and by applying the Laplace transform, one obtains

$$2Hs^2\Delta\omega(s) + \sum_{i=1}^{n}\frac{k_i}{T_i}\Delta\omega(s) = -s\Delta p_D(S) - sp_{lost}(s) \qquad .....(4)$$

and perform inverse Laplace transform yields to $\Delta w(t)$.

$$\Delta\omega(t) = -\frac{p_{lost}}{\sqrt{2H\sum_{i=1}^{n}\frac{K_i}{T_i}}}\sin\left(\sqrt{\frac{1}{2H}\sum_{i=1}^{n}\frac{K_i}{T_i}}.t\right) \qquad ......(5)$$

The minimum frequency deviation is given by

$$\Delta\omega_{min} = -\frac{p_{lost}}{\sqrt{2H\sum_{i=1}^{n}\frac{K_i}{T_i}}} \qquad ....(6)$$

The oscillation period of the simplified power system model is given by

$$T_d = \frac{2\pi}{\sqrt{\frac{1}{2H}\sum_{i=1}^{n}\frac{K_i}{T_i}}} \qquad ....\ (7)$$

Table -1: UC's POWER AND ENERGY CAPACITIES

Power (MW)	Energy(MWs)
4	4 X 5.3

Maximum generating time is given by,

$$t_{gen,max} = \frac{T_d}{2} \qquad ....(8)$$

Equation (6) allows estimating the critical power loss for which frequency will just reach the minimum allowable frequency:

$$p_{lost,c} = -\Delta\omega_{min}\sqrt{2H\sum_{i=1}^{n}\frac{K_i}{T_i}} \qquad ....\ (9)$$

The difference between the disturbance and the critical loss. Then p_{UC},

$$p_{UC} = P_{lost,max} - P_{lost,c} \qquad ......\ (10)$$

Equation (10) accept that the UC about its most extreme force yield, Then E_{UC} is given by,

$$E_{UC} = P_{UC}\,t_{gen,max}. \qquad ....(11)$$

Note that (7) and (9) require per unit values. For the Spanish force framework and considering with k_i =6.3, T_i =10s, H=0.9s and Δw_{min} =0.06 pu, $t_{gen,max}$ is around 5.3 s and $p_{lost,c}$ is around 6.4 MW. Since maximum power loss is 10.4 MW, p_{UC} results to be 4 MW..

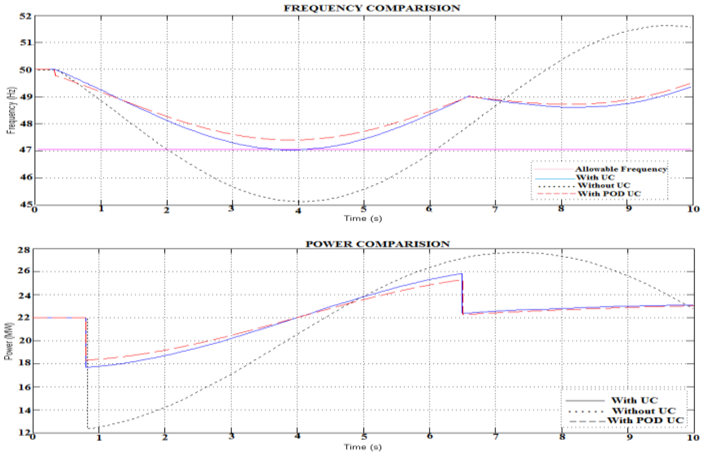

Fig -2: Comparison of the power system responses in terms of frequency and total power generation with, without and with POD UC.

4. ULTRACAPACITOR MODEL

The straight model of the UC can be then detailed as takes after:

$$\Delta p_{UC}(S) = -\left(\frac{1}{R_{UC}} + \frac{2H_{UC}S}{1+sT_f}\right)\frac{1}{1+sT_c}\Delta\omega(s)$$

$$= -\frac{1}{R_{UC}}\frac{1+s(2R_{UC}H_{UC}T_f)}{1+s(T_f+T_c)+s^2(T_fT_c)}\Delta\omega(s) \qquad \text{....... (12)}$$

Fig -3. demonstrates the rearranged nonlinear model of the UC. This model incorporates a dead-band Δw_{db}, the force yield restrictions $\Delta_{PUC,min}$ and $\Delta_{PUC,max}$ the vitality yield confinement $E_{UC,max}$ and a tail control is also included. This control fluctuates the upper force yield limit $\Delta_{PUC,max}$ in capacity of the utilized vitality E_{UC}.

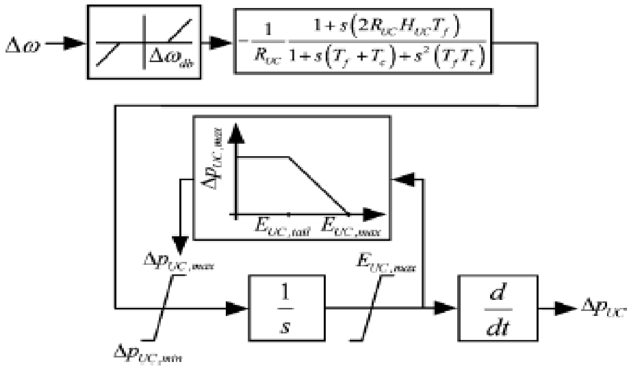

Fig -3: Simplified model of the UC.

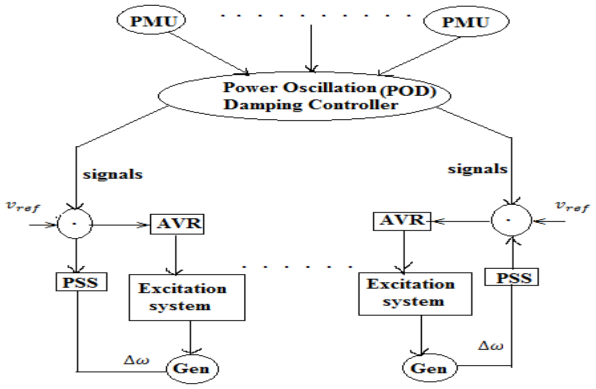

Fig -4: General structure of POD Controller

By using power system stabilizer (PSS), the impact of UC on UFLS scheme has been designed by the system operator such that the power system is able to reduce the responses by means of power oscillation damping controller connection withstand such that frequency stays above 47 Hz. In a second step, a sensitivity analysis with respect to the control parameters and the size of the UC is presented.

5. IMPACT OF POD UC ON UFLS SCHEME

In this section, by using power system stabilizer, reduced the system responses by means of power oscillation damping controller and presented the comparison among with UC, without UC and with POD UC are presented below.

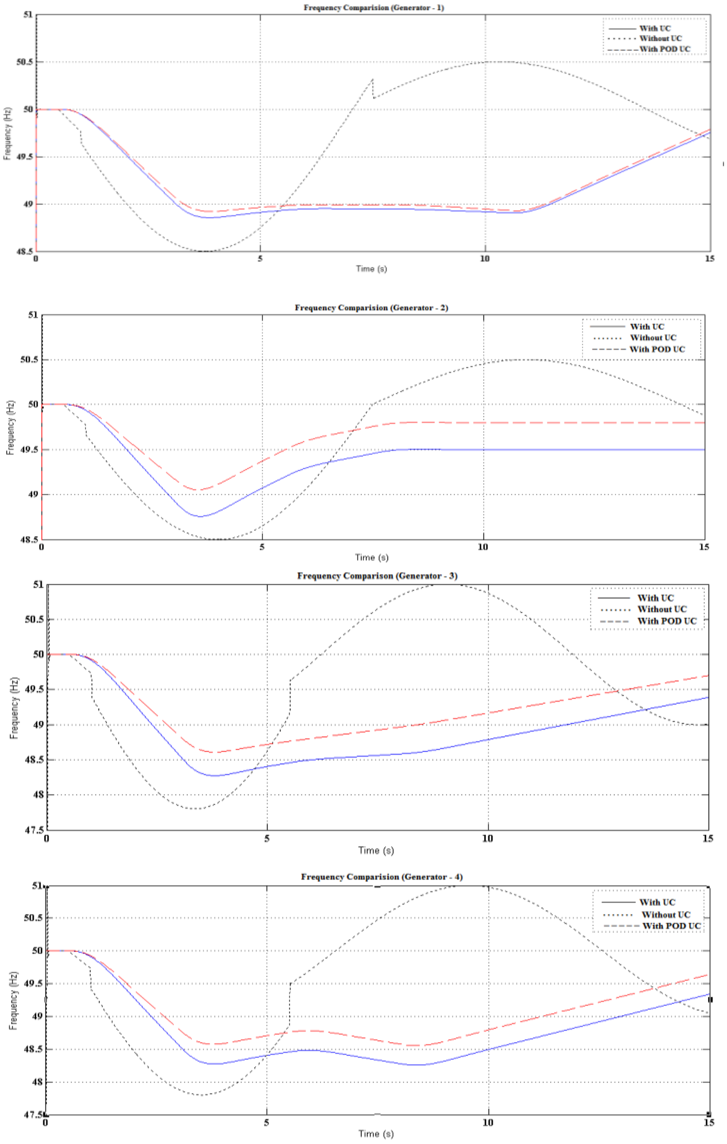

Fig -5a: Comparison of the system responses in terms of frequency

Fig -5a. shows and compares the power system responses in terms of Frequency among With UC, Without UC and with POD UC in four generating Units of different magnitude and it shows the frequency deviation has been reduced, the ROCOF has been increased and that shedding of the first under frequency stage has been prevented to fast power injection by the UC. Similarly, POD of the second under frequency stage has been prevented for a slightly larger outage in other generating units in order.

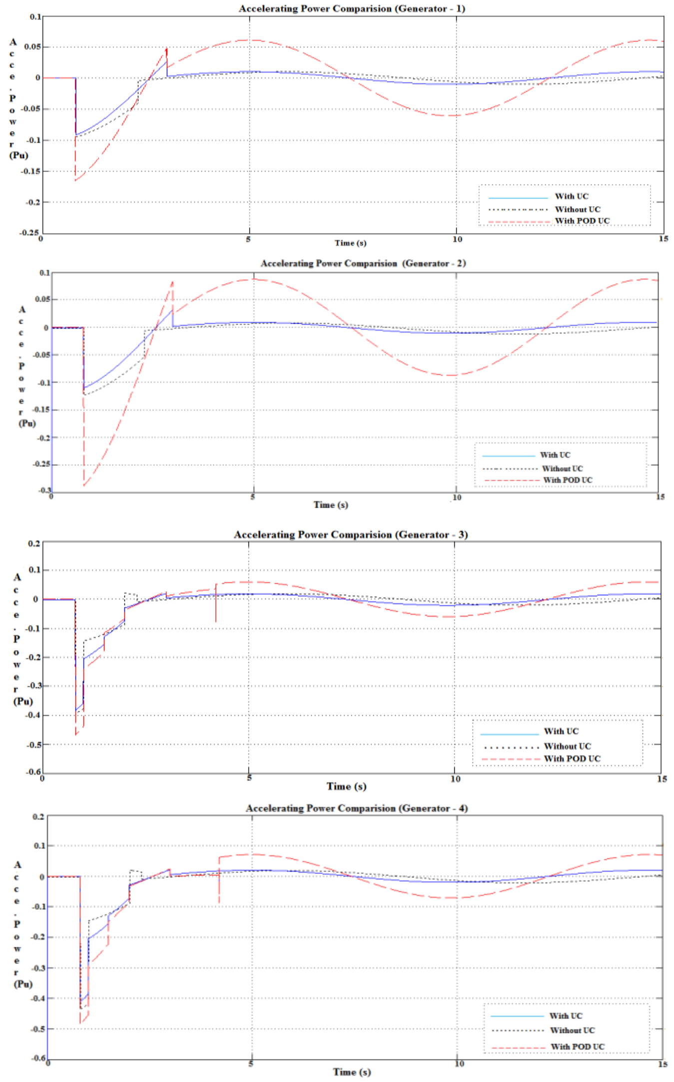

Fig -5b: Comparison of the system responses in terms of accelerating power

Fig -5b. represents the power system responses in terms of accelerating power among With UC, Without UC and with POD UC in four generating units of different magnitude and it shows the UC has prevented the ROCOF UFLS stages from acting and only the first two under frequency stages have actuated. UC power reduction due to the tail control can also be observed around time = 4.3 s. Accelerating power diminished investigating a reduction in frequency.

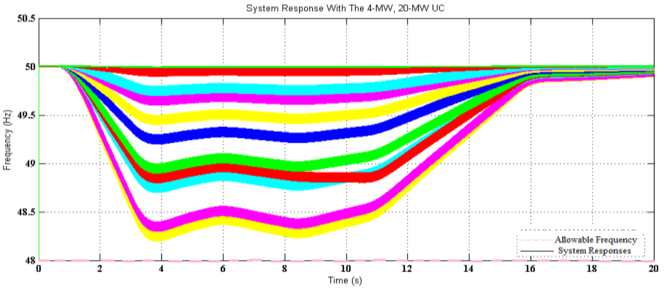

Fig -6: System response with the 4-MW,20-MW POD UC

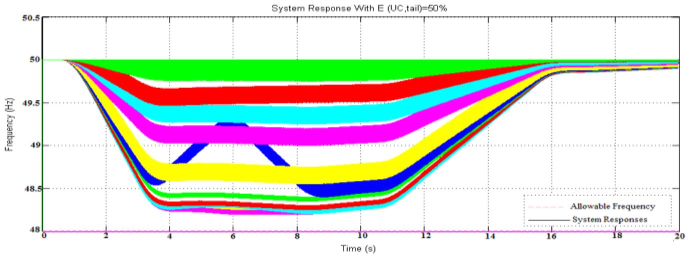

Fig -7: System response with POD $E_{UC,\ tail}$ =50 %

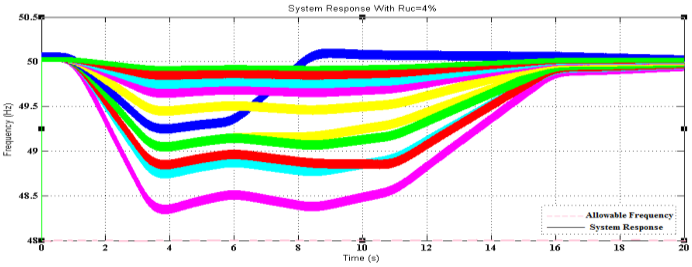

Fig -8a: System response with POD R_{UC} =4 %

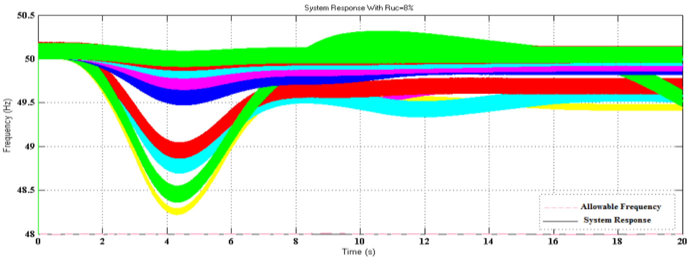

Fig -8b:. System response with POD R_{UC} =8 %

Fig -8a. and Fig -8b. shows the frequency variation in between the droop of 4% and 8% . if droop of the UC is low, then the frequency deviation increases as with respect to the POD.

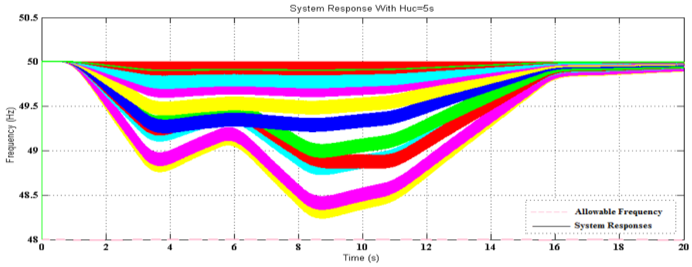

Fig -9a: System response with POD H_{UC} =5 s

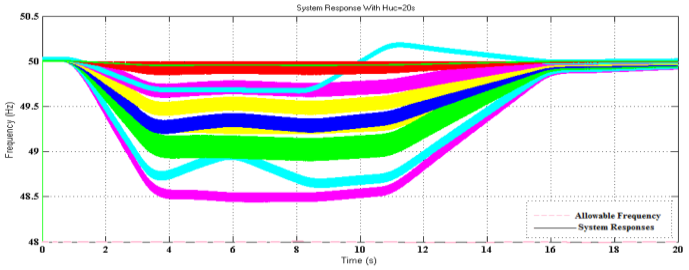

Fig -9b: System response with POD H_{UC} = 20 s

Fig -9a. and Fig -9b. shows that when emulated inertia increases, the frequency deviation slightly changes.

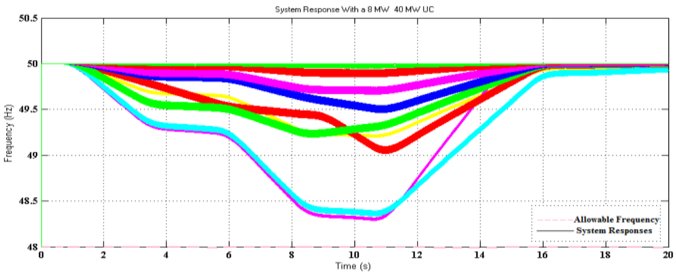

Fig -10: System response with POD UC of 8MW 40MW

Fig -10. shows the response of frequency deviation. If the load increases, the frequency deviation is easily approaching steady state.

TABLE -2: TOTAL AMOUNT OF SHED LOAD

Type	P_{shed} (MW)
Without UC	274.91
With UC	35.72

It can be seen that the UC clearly decreases the amount of shed load. This is due to the fact, that larger outages of the UC avoided all ROCOF relays to act and only some under frequency relays were necessary, where as for medium-sized outages the need for under frequency relays has been minimized.

TABLE -3: AMOUNT OF SHED LOAD IN FUNCTION OF VARYING CONTROL PARAMETERS

Energy tail controls	P_{shed} (MW)		P_{shed} (MW)
Default	35.72	R=1%	41.54
w/o tail control	36.2	R=4%	42.92
$E_{UC,tail} = 50\%$	35.72	H=20s	32.11

Table -3. shows without tail control or with a low value for E_{UC}, the amount of shed load increases with respect to the default control parameter settings. similarly, if the droop is too low or too high, the amount of shed load increases.

TABLE -4: AMOUNT OF SHED LOAD IN FUNCTION OF THE SIZE OF THE UC

UCs size	P_{shed} (MW)
4 MW-40MW	35.15
8 MW- 40MW	34.39
2 MW- 20MW	99.44

Table -4. shows the impact of the UC size on the amount of shed load. Default controller parameter settings Have been used (i.e., $R_{UC} = 0.02$, $H_{UC} = 10\ s$, $T_f = T_c = 0.2\ s$, $E_{UC,tail} = 70\%$). An increased storage capacity has a very small impact. similarly, an increased power capacity has a small effect too. However, reducing power by 50% clearly increases the amount of shed load. This indicates that the initially estimated size of the UC is approximate.

TABLE -5: IMPACT OF TAIL CONTROL AND DROOP CONSTANT IN CASE OF A LARGE UC

Parameters	8 MW – 40MWs	4 MW – 40MWs
$E_{UC,tail} = 50\%$	27.91	35.15
$R_{UC} = 4\%$	25.07	42.92
$R_{UC} = 8\%$	30.98	97.98
$H_{UC} = 20s$	29.15	25.07

In case of larger UCs, different values for the control parameters might improve the UC's impact (different control parameter settings did not affect the smaller). A further analysis of the control parameters has been carried out as shown in Table -5. It can be seen that in case of the 8 MW – 40 MWs UC, a smaller value for $E_{UC,tail}$ is beneficial in terms of shed load.

TABLE -6: PARAMETERS OF UFLS SCHEME

	Under Frequency		ROCOF				
Stage	$\omega\ (Hz)$	Tint (s)	$\omega\ (Hz)$	dw/dt (Hz/s)	Tint (s)	topn (s)	P_{shed} (%)
1	48.65	0.15	49.7	-2	0.1	0.2	10.0
2	48.15	0.15	49.1	-2	0.1	0.2	3.07
3	47.9	0.1	49.7	-2	0.1	0.2	4.16
4	47.9	0.1	-	-	-	0.2	6.91
5	47.8	0.1	49.7	-2	0.1	0.2	1.84
6	47.5	0.1	-	-	-	0.2	6.67
7	47.1	0.1	-	-	-	0.2	5.70
8	46.8	0.1	49.1	-2	0.1	0.2	8.34
9	46.5	0.1	-	-	-	0.2	5.84
10	45.5	0.1	-	-	-	0.2	5.70

TABLE -7: PARAMETERS OF THE GENERATING UNIT MODELS

Generator	Mbase(MVA)	H(s)	K	B1 (s)	b2(s)	A1 (s)	a2 (s)	P_{min}(MW)	P_{min}(MW)
G11	5.4	2.47	20	1.45	0	16.57	4.01	2.5	4
G12	5.4	2.47	20	1.45	0	16.57	4.01	2.5	4
G13	5.4	2.47	20	1.45	0	16.57	4.01	2.5	4
G14	6.3	2.44	20	1.47	0	16.61	4.12	3	4.5
G15	9.4	3.05	20	1.15	0	15.45	2.39	3.5	7
G16	9.6	3.04	20	1.15	0	15.45	2.41	3.5	7
G17	15.75	2.98	20	1.16	0	15.48	2.45	7	12
G18	26.82	6.5	21.25	1.52	0	3.52	1.36	0	22.8
G19	14.5	2.96	20	1.17	0	15.48	2.45	7	12
G20	14.5	2.96	20	1.17	0	15.48	2.45	7	12
G21	14.5	2.96	20	1.17	0	15.48	2.45	7	12

6. CONCLUSION

In this paper, a systematic design procedure for power oscillation damping control systems is described. A centralized structure is proposed for such systems, power and frequency on good choices for stabilizing signals with respect to power system stabilizer (PSS) For the small size system considered, one stabilizing signal is enough for the input of a POD controller. Multiple inputs improve the control performance only slightly for such small systems but are expected to be necessary for acceptable control performance in large systems. This paper has examined the effect of the size and the controller settings of a UC on recurrence solidness and specifically, on the execution of the UFLS scheme of Spanish isolated power system. The execution of the UFLS scheme has been utilized as a measure for the upgrade of frequency stability on account of the UC.

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