

An Adaptive Fuzzy-PD Inertial Control Strategy for a DFIG Wind Turbine for Frequency Support



ovpk Gr wkn. 0Zsw Rs vo' 0a k-spTkoow

Kx o' qKAYo' kxn Q-owsqox-I yx 'yvyYnr yyvypKvoma-yx smaOKvoma-snkKx qsx oo' sx q kxn I ywz o-e' Ynsxno Woox -[xsi o' s-KAYok-0Hoyk-0f Q

GHYZ I Z@ s-sx mok-sx q voi ov-ypó sxn qox o' k-syx sx zyó o' -KAew-0qok' kx-oesx q nyx-sx oyó-zyó o' kxn -KAew*-kpo-KA s-o-ox-ka2L' o' ooxnKAYx 'yvs-mis-snkvo r snr 'o' os' o-k-ozz vov ox k-KA o' skvnyx 'yv-'k-ekQYsxnó ó sxn zyó o' qox o' k-syx noz oxn-ns' omKAYx ó sxn nyxns-syx-0+s- mok-e- lx sw w ox-o nr kvox qo py' k nyxi ox-syx kvxs o' skvnyx 'ywo' ó s-s-zk' kw o-e- -os-ld vo py' kwzyó o' q' sn yz o' k-syx-kxn ó sxn-zoon nyxns-syx-2' o' opy' o' o-ox sx q-+o nyx 'ywo' qksx-s-kl-yw-ekKAs-snkpy' kx sx-ek' k-en nyxi ox-syx kv3' ox oó kl vo zyó o' -KAew 2No' oOk p' Thiky qsmknkz-si o' s-o' skvnyx 'ywo' -nr ow o py' yx sx o-ox sx q py-+o z' yzy' -syx kvno' sí k-si o-1-KA o' , VJ -s- o' skvnyx 'ywo' z' k' kw o-e- -s-z' yzy-on2' o z' yzy-on nyx 'ywo' knkz-+o nyx 'yv z' k' kw o-e- -yp-+o-ozz vov ox k-KA o' skvnyx 'yvypp-+o nyó l KAn sxnomsyx qox o' k-y' , J LOM ó sxn-e' l sx o-y-+k-és-s- lx KA ns-e' l kxn-omr k-wkn nr kx qo-0-+o kms-ó zyó o' yó-zó-nkx l o nyx 'ywon-y-ws-sqk-e-+o p' o' ooxnKA o' sí k-syx 2Ysw ok-syx 'o-ov-sxnsnk-e-+k-+o z' yzy-on knkz-si o' nyx 'ywo' nowyx-'k-e- k wy' o' nyx-s-ox-kxn 'yl o-'o-zyx-o-y-wkn nr kx qo-nywz k' on-y-k nyxi ox-syx kvnyx 'ywo' ó s-s- Roh z' k' kw o-e-2

QoKAY' n-@ sxn ox o' qKAYo' k-syx Anyol vKAn sxnomsyx qox o' k-y' , J LOM Ap' o' ooxnKAYx 'yvaux o-smox o' qKAK-e-yp nr kx qo ypp' o' ooxnKAYy l yL-2

1. INTRODUCTION

o xono-sKAXn nr kvox qo yp k 'onomsyx sx I U_o ows-syx-noo-y-s-no-sw ox-lev o om-yx ox i's yx w ox-0k-ó owk-sx-o' kxn kxn nok' +yp-yo' no--omr k-py-svpo0r k-von-y-oi o' kvnyox 'so-kq' oon-y' ks-o-+o zox o'-k-syx voi ov ypxyx l-kns-syx kvkxn 'ox oó kl vo qox o' k-syx-yo' no-2a sxn ox o' qKAYx z' k'-s-nok' Os-nyx-sno' on-y l o' k' ovskl vo' ox oó kl vo ox o' qKAYo' no py' ovom-sns-KA' ynomsyx +o' opy' o' oz-knsx q nyxi ox-syx kv qox o' k-syx pyw 'kns-syx kv +o' wkv p' oov-ozz vso-, qk-0y svkxn nykv k-k' k' qo -nkwo2Gv+yoqr r sqr l voi ov ypx-s-ek' k-syx ypkv-e-xk-e-ox o' qKAYo' no-0zk' -s-nok' vKA ó s-s-kx sx mok-o sx +o zox o'-k-syx ypó sxn zyó o' sx-y-+o xy' wkv q' sn0 nkx l o l oxo nsko0s-nyovn r ki o' ox o' Rvomen 'o-ov-ó r snr nyovn nyox-e-kna-+o' ovskl ss-KAn +o-ld ss-KA yp no' 'ox-'kns-syx kv zyó o' -KAew- e5g2' o o-0 yp +o J LOM l k-on ó sxn-e' l sx o' qox o' k-y' , a ZM r k- q'yó x 'kz snvKAsx no' o-x yp +o 65-nox-e-KAQ k J LOM +o qox o' k-y' p' o' ooxnKAKx í k' KA- +o ó sxn-zoon nr kx qo-0 ó r snr kwyo- +o a ZM-y-zy o' k-e-k-ns o' ox-é sxn-zoon sxn oz ox nox-yp-+o p' o' ooxnKAn í yv-ke qo yp +o q' sn e6g2'

Toi o' +o-0-0ó r ox +o xow l o' yp J LOM-s- sx mok-on sx nowok-si o' zox o'-k-syx kxn ó r ox nyx xomen-y-+o zyó o' q' sn0-+o p' o' ooxnKA-ld ss-KApk zyó o' -KAew wkKAomsx o2 YKAew sx o' -sk-s-k uoKAmny-0sx no-e-ws sx q-+o-ox-s-s-s-KA yp-+o p' o' ooxnKAY-kx KAvl kx xn l o-é-oox qox o' k-syx kxn wkn e7g k-s-k om-+o 'k-e-yp nr kx qo yp p' o' ooxnKA , Xyl yL- k o' kx KAp' o' ooxnKA o' -2G' onomsyx sx -KAew sx o' -sk ó sw vokn-y-k 'kz sn n' yz sx -KAew p' o' ooxnKA-+o-k omsx q-+o Xyl yL sx mok-sx q-+o vsuovr yyn ypy-ox-ek -KAew nyvkz-o

YKAew p' o' ooxnKA-nyx 'ywon yx k-onyx nll KAnyx n l k-s-l KAKvnsx q-+o zyó o' -ozz vKAn nowkxn py' ovom-sn

zyó o' -KAew-2Z' kns-syx kv zyó o' zvkx-ó s-s-KAn' yxyo-qox o' k-syx zkkKAX o-ox-ekv' yvo sx nyx 'ywsx q-+o p' o' ooxnKA -sxnno-+o KA k' o' k' k' qo sx o' -sk-nyx-lex-e8g2' -okvKA ó sxn-e' l sx o- k' o no-sxon-y-zy o' k-e-y- sx mok-o-+o' o' 0-+o' kms-ó zyó o' ó xnno' í k' syo-ó sxn zyó o' nyxns-syx-r yó oí o' 0-+o' kms-ó zyó o' s-wksvKA o-e-wsxn l KA-ó sxn-zoon2' o 'y-y' -zoon yp k J LOM +o' opy' o' s-nonyovon pyw +o -KAew p' o' ooxnKA o-0J LOM kms-ó zyó o' yó-zó-owkx-nyx-lex-é s-s- kx KAn kx qo- sx +o -KAew p' o' ooxnKAG- k 'o-ov-+o J LOM w-xy-z' ynomo kx KAnns-syx kv' s-o sx +o kms-ó zyó o' yó-zó-2Nox no0sx k zyó o' -KAew ó s-s-k r sqr voi ov yp ó sxn zyó o' zox o'-k-syx 0 kxn +o' opy' o' 'ononon -KAn' yxyo- sx o' -sk0 +o -KAew p' o' ooxnKAKm- k- kx sx nsnk-y' yp kx KAw l kx xn l o-é-oox qox o' k-syx kxn wkn pywó sx q wkn ns-e' l kxn y' qox o' k-y' -sz sx q0 py' o' RkAvzvo2

o o om-yp J LOM zox o'-k-syx sx k zyó o' -KAew rk-l oox sx i o-sqk-en sx e9l; g2O+ k-l oox-ryó x-+k-é s-s-yo-lex knns-syx kv-ozz vov ox k-KAYx 'yv wyz knnon-y-+o J LOM nyx 'ywo' 0-+o nyx 'yv -KAew km-kqkx-+o nr kx qo- sx +o -KAew p' o' ooxnKA-+o' opy' o' 'o-zyxnsx q ó s-s- k Tdi y' x oqsqsd vo sx o' -skv' o-zyx-o2Q; 156g0-+o p' o' ooxnKA ozz y' -pxmsyx yp k a ZM +k-0-0- sx o' -skv nyx 'yv-owzy' k' skKA 'ovok-0-+o QK-y'on sx +o 'y-k-sx q wk-yp k a ZM-y-swz' yio +o p' o' ooxnKAKns' no' sx q-+o sxs-sk3-kx-sox- -kqo-ypk ns-e' l kxn2

G z' yzy' -syx kvno' sí k-si o' , VJ -1-KA o' nyx 'ywo' s-nyw wyx vKA-on sx zyó o' -KAew- py' p' o' ooxnKA oqok-syx 2

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Gv+y0qr0 r+s-nyx 'ywo' s-swzvo kxn o-ekwKa oms'o0s-
 zo'py'wknno s- kknkKaws-on lKa' -smysx-yp-'kns-syxkv
 VJ nyx-yv n0o y qok'kx-on novio'KApp yz-sw0w
 zo'py'wknno e56I57g2Q e58g0kVJ is'ekvsxo' skvnyx-'ywo'
 ,] O -ok-on sx +o kms'io zy0'o' nyx-'yvypJ LOM-20 ek-
 nowyx-'k-on +k-0s+ +o z'yzy-on '-om0'o0 +o
 nyx-'ywo' qkx zk'kwo-e'-yp +o VJ] O ny0n lo -0xon
 yxvxo y-z'oi ox +o -KAow p0' 00xnKA yw pksxq yy w0
 0 rso wks-ksxq +o 'y-y' -zoon 0s+sx kx yz'o'k-sxq vws-2
 o swzkm-yp VJ zk'kwo-e'-rk-l oox sxio-sqk-on sx
 e59gx y'no' y-nywzk'o0nyx-'k-kxn-o-kl oxnwk' u0s+
 +o ksw ypn0i oyzsxq kx kv0-xk-s0 nyx-'yv-'k-eqKAr snr s-
 kl wo y-oxr kxn p0' 00xnKA nyx-'yvkxn o oms'ovKaw ek-e-
 sx'o'-sk2

Q e5: g0k 'ovok-ld to QKil k-on sx'o' skvnyx-'yv-nr ow o
 py' J LOM 0 sxn zy0'o' z'vz-ek-z'yzy-on +k-ns o'ox-sk-e-
 +o J LOM'-nyx-'s' 0-syx noz oxnsxq yx s-'ovok-ld to QK2 o
 -nr ow o knto- +o qkx-yp +o Xyl yL kxn n'yzy nyx-'yv
 wyz sx +o J LOM nyx-'ywo' noz oxnsxq yx +o 'y-y' -zoon
 z'sy' y k ns-e'l kxn2 o 'o-ov- nowyx-'k-on kx
 swz'y'ow ox-sx +o -KAow p0' 00xnKA kns' nywzk'on y-+o
 nyxi ox-syxkvnyx-ks-qkx-nr ow o2

Q e5: g0k p0' THKA ysmnyx-'ywo' py' sx'o' skvnyx-'yvyp
 a ZM- s- z'yzy-on2 Ysw0k-syx 'o-ov-xy-on +k-+o
 z'yzy-on -nr ow o nkx lyy- +o p0' 00xnKA kns' pyw0sxq
 +o nomx0 yp +o -KAow p0' 00xnKA- yzzy-on y-+o
 nyxi ox-syxkvnyx-'yv-nr ow o2

G xyi ov knkz-s0] O y-lyy-lyr- +o p0' 00xnKA
 -ld ss-KAxn sx-e'lk'ok y-nsvk-syx-s- z'yzy-on sx e5<g2 o
 qkx yp +o -0qo-on] O s-nKkwsnkKAnto-en 0-sstxq
 p0' THKA ysm 0s+ 'o-zom-y- sx-e'lk'ok y-nsvk-syx-2 Yoio'kv
 p0' 00xnKA i ox-0nr k-r'y'-ns n0s-ns-e'l kxn0 0s+ wkn
 -ronnsxq kxn w-yp qoxo'k-syx k'o 0-on y-k-0- +o
 nyx-'yv kxn o ns0xnKA o'py'wknno yp +o knkz-s0 p0' THKA
] O 2 Ysw0k-syx 'o-ov-ns-z'vKkA +k-+o z'yzy-on p0' THKA
] O -nr ow o nkx z'yisno swz'yion zo'py'wknno +kx +o
 -'kns-syxkv Roh qkx] O py'lyr- -KAow p0' 00xnKA ld ss-KA
 kxn +o sx-e'lk'ok y-nsvk-syx-2

G p0' THKA knkz-s0 knns-syxkvsxo' skvnyx-'yv-omxs' 0o s-
 qsi ox sx e5=g py' p0' 00xnKA oqovk-syx y-knto- +o z'yzy' l
 -syxkv kxn no's'k-s0 nyx-ks- knkz-s'ovKA k-on yx +o
 p0' 00xnKA o' sk-syx kxn +o p0' 00xnKA o' sk-syx nr kxqo'k-e-
 0xnno' wkn ns-e'l kxn0-y' 0sxn -zoon2 o no's'k-s0 kxn
 z'yzy' -syxkv nyx-ks- ikwo- sx -'kns-syxkv sx'o' skvnyx-'yv
 k'o knto-en l KAsw0k-sxq +o -k-sm nr k'kme's-sm kxn
 sx'o' skv 'o-zyx-o nr k'kme's-sm yp +o nyxi ox-syxkv
 -KAm'yxy0-qoxo'k-y'2 o z'yzy-on -nr ow o s-ny'ovk-on
 0s+ -'kns-syxkv knns-syxkv sx'o' skvnyx-'yv-'k-eqKAxn
 usxo-smoxo'qKAQK- ll k-on qkx 2 Ysw0k-syx 'o-ov-xy-e-+k-
 +o z'yzy-on -nr ow o nkx z'yisno knns-syxkv p0' 00xnKA
 -0zzy' -no'sxq wkn ns-e'l kxn0-0nm0-p0vKAxn kv-y
 'oz'o- +o p0' 00xnKA k' sk-syx wkno l KA-0 sxn -zoon
 omok-syx2

s- zkzo' z'yzy-o- kx knkz-s'olsxo' skvnyx-'yv
 -nr ow o py' k J LOM a ZM 0s+ zk'-skv-nkvo p0' 00xnKA
 nyxi o'-e', ZKA I - 0-sxq k p0' THKA ysm-nr ow o py' p0' 00xnKA
 'oqovk-syx sx zy0'o' -KAow-2 G p0' THKA ysm k-on knkz-s0
 nyx-'yv-'k-eqKA- swz'vow ox-en r'o'o y-yl-ksx 'yl-0-kxn
 knno'k-e-nyx-'yv zo'py'wknno k- 0ow k- pk-e' p0' 00xnKA
 'o-zyx-o 0s+ -ld wo -KAow yzo'k-syx no'sxq +o -sw0 ypkx

oi ox-2 o z'yzy-on nyx-'yvk0-ywk-skvKAnto- +o J LOM
 nyx-'ywo' zk'kwo-e'-yxvxo y- +k-+o sx'o' sk-pyw 0sxn
 -e'l sxo-nkx lo 0-s0-on y-nomok-o +o nr kxqo sx p0' 00xnKA
 ik' sk-syx kxn +o opy' o oxr kxn0 +o p0' 00xnKA kns' no'sxq
 +o -'kx-sox-zo'syn-2

Q r+s-0nKA-0 swzkm-yp0 sxn qoxo'k-syx yx ovom'sm
 zy0'o' q'sn- kxn xo-0y' u- 0s+ zk'-smvk' nyx-smo'k-syx yp
 +o o om-yx -KAow p0' 00xnKA k- l oox oRAv sxon2 o
 0y'u rk-l oox kxkvKAnto kxn ns-no-on y-snox-sKA-0 wks
 z'yl wov nko-on l KA-0 sx-eq'k-syx yprsqr voi ov-yp 0sxn
 zoxo'k-syx kxn s-n's0ma-swzkm-yx zy0'o' -KAow -ld ss-KA
 0 rsnr k om-'ovkl ss-KAxn +o yzo'k-syxkvzo'py'wknno yp
 zy0'o' -KAow-2

o zo'py'wknno yp +o z'yzy-on -nr ow o s-0nson
 0xnno' ik'sy0- -KAow nyxns-syx- kxn nywzk'on 0s+ +o
 0snoKAnto-on VQ l k-on nyx-'y2 o 'o-ov-sxnsk-e-+k-+o
 'yl 0-xo-yp +o knkz-s0 nyx-'ywo' y-kxKAvkn nr kxqo-s-
 q'ok-e' +kx +k-yp +o nyxi ox-syxkv nyx-'ywo' 0s+ Roh
 zk'kwo-e'-2 Q-s nowyx-'k-on +k-+o kms'io p0' 00xnKA
 'o-zyx-o yp +o zy0'o' q'sn 0s+ rsqr 0sxn zy0'o'
 zoxo'k-syx nkx lo -sqxs nkx-KAxr kxn on2

G p0' 00xnKA o' sk-syx wyz ,n'yzy wyz- rk-l oox
 nr y-ox sx r+s- 0y'u -sxn0 s-kwy0- y- kv oxo'qKAs-nr k'qo2
 s-nyx-'yv-'k-eqKA k- l oox noi owz on y-0-o ns o'ox-
 ikwo-yp noi sk-syx wyz qkx-0l k-on yx z'oi sy0-0y'u sx
 e64g2 Ny0 oi o'0 +o p0' 00xnKA o' sk-syx qkx ikwo s-ik'son
 yxvxo k- k p0xmsyx yp +o zy0'o' -KAow p0' 00xnKA
 noi sk-syx-2 o qkx yp +o Xyl yL , Qz- wyz sx +o
 z'yzy-on -nr ow o s-wks-ksx on k-nyx-ks-0 rso +o n'yzy
 p0' 00xnKA o' sk-syx wyz qkx , 53X- nr kxqo-ko-ywk-skvKA
 0s+ -sw o2

Q knns-syx0 +o z'yzy-on Gnkz-s0 L0' THKA J Qo' skv
 l yx-'yv-nr ow o s-nywzk'on 0s+ +o z'oi sy0-0y'u sx e64g0
 0 rsnr rk-l oox noi owz on y-0-s0 ns o'ox-ikwo-yp +o
 noi sk-syx py' p0' 00xnKA oqovk-syx 0-sxq i k'skl wo qkx-sx +o
 p0' 00xnKA o' sk-syx wyz py' +o sx'o' skvnyx-'ywo' kxn wyz
 nyx-'yv qkx-, kms'io qkx- l k-on yx nr kxqo ypp0' 00xnKA
 o -0y kzz'yknr o-wox-syx on klyio z'o-o'io -ld wo
 yzo'k-syx ypk J LOM kxn smok-o +o p0' 00xnKA kns' sx
 nywzk's-yx y-nyxi ox-syxkv Roh qkx -nr ow o-2 Q-nkx
 +o opy' o l o nyxmonon +k-l KAv' om-knto-wox-ypsx'o' skv
 nyx-'ywo' zk'kwo-e'- +o zo'py'wknno 0sw lo q'ok-KA
 swz'yion2 Ny0 oi o'0 wkv0kv -0sxq s- n0wl o'-ywo kxn
 'o' 0s0-'skvkn o'y'2

o 'o-ov- z'o-ox-on sx r+s-0nKAnywzk'o- +o
 zo'py'wknno yp +o z'yzy-on p0' THKA k-on nyx-'yv0xnno' +o
 -kwo p0' 00xnKA i ox-l o-0-0ox +o pyw0sxq py0' nk-o-@
 J LOM 0s+y0-nyx-'y0 +o z'yzy-on p0' THKA k-on nyx-'y0
 J LOM 0s+ nyxi ox-syxkv Roh qkx 0 kxn J LOM 0s+ kms'io
 n'yzy nyx-'y2

Gw +o 'o-ov-nyx 'w +o z'yzy-on Qo' skv l yx-'yv
 -'k-eqKAntx swz'yio +o p0' 00xnKA kns' kxn qok'kx-00
 -0knKAv o'k-syx ypk J LOM2

Gnns-syxkvKAnto +o z'yzy-on wo-ryn 'o' 0s0-xy ok'wo'
 uxy0v onqo'y' wk+owk-skvwynovyp +o -KAow 2 Gv yzok-o
 xy-e-+k-+o p0' 00xnKA-on sx r+s-zkzo' s-: 4 NThx y'no'
 y-wkwo k pks' nywzk's-yx 0s+ +o nyxi ox-syxkv sx'o' skv
 nyx-'ywo' 00 rsnr 0k-swz'vow ox-en 0-sxq +o: 4 NThKAow 2
 o zkzo' s- y'qkxst0n sx io -omsyx-2 Yomsyx 6
 z'yisno- ywo l kmq'y0xn yx +o nyxi ox-syxkv sx'o' skv

'o-zyx-o yp k J LOM2 Yomsyx 7 oRaks- +o pTHKAyqsm
 -KAew no-sq kxn wynowsq2ToRto z'yzy-on nyx-yv
 -k-ekKA-z'o-ox-en sx Yomsyx 8 órs- Yomsyx 9 -ryó- +o
 -swok-syx-'o-ov-kxn ns-no-syx-2LsxkwKA+o nyxmo-syx-
 +k-nkx lo n'kóx pyw +o kxkKA k'o z'yísnon sx
 Yomsyx : 2

2. THE CONVENTIONAL INERTIAL CONTROL OF A DFIG

oJ LOMs-nonyozvon pyw +o q'sn nso -y-kl km1-y1
 l km1 GI 3J I 3GI nyxí'o -y'2I yx-o' oox-ko+o ovom-yxsn
 nyxí'o -y' nonyozvo- +o qoxo'k-y' -zoon pyw q'sn
 p'ó' ooxnKA65g2 ozyó'o' ovom-yxsmnyxí'o -y' oxkl vo- +o
 J LOM -y- nkz-é'o' ósn oxo'qKAkxn 'okm +o wkRvow
 o nsxnKAyí'o' k'ó s'no 'kxqo yp ósn -zoon-2J LOM- k'o
 knkz-en -y- nyx-ka-VAkv-e' +o 'y-k-syxkv -zoon kxn
 +o' opy'o +o kmsí-o zyo'ó' ypósn -é'l sxo-k-í'k'syo-ó'sn
 -zoon- -y- oxrkxno / oks-KAp -ozzVKAkxn -y' oqovk-é +o
 kmsí-o k- óow k- +o 'okmsí-o zyo'ó' 2Nyó oí'0'noo -y- +o
 nonyozvxqyp +o 'y-k-syxkv-zoon pyw +o q'sn p'ó' ooxnKA
 +o J LOM z'ynono- xy 'o-zyx-o -y- nkxqo- sx -KAew
 p'ó' ooxnKA9g2O-s-ryó oí'ó' zy-d vo py' k'ó'sn -é'l sxo -y-
 nyx-d' o-é -y- +o -KAew sxo' -sk kxn -ozzy' -+o p'ó' ooxnKA
 nyx-yv l KAknsxq k -ozzvowox-k'KAsxo'-skv nyx-yv2
 Kxr kxnów ox-yp-oni k-ozzvowox-k'KAsx-yvpy' swz'yí on
 p'ó' ooxnKAozzy' -s- +o wksx -ól tom-yp+s-zkz'ó'2

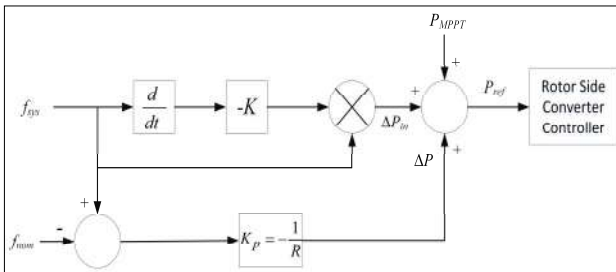
s- óy'u k-owo- +k-+o nyxí'ox-syxkv sxo' -skv
 nyx-yv-nr owo ypkm J LOMsxmno- -éy nyx-yvvyz-@-
 +o XyI yLA kxn 6- p'ó' ooxnKAnoí sk-syx wyz-2 Hy-+
 pool km1-nr owo-k'ó' o-ss-ón -swov-lex oyo-VA-oxrkxno +o
 -KAew p'ó' ooxnKAyx-yvyp+o J LOMk-z'o-ox-en sx e56g0
 e66g0e67g2 o -kns-syxkv sxo' -skv nyx-yv-nr owo s-ryó x
 sx Lsq25 ór'ó'ox +o sxxo' nyx-yvvyz s- +o XyI yL wyz
 , V_s- ór'ó'ok- +o yó-é' yxo z'o-ox- +o p'ó' ooxnKA
 í'k-sk-syx wyz y' n'yyz lyyz , V-2Qkxn 53X k'o +o qksx-
 ypXyI yL kxn noí sk-syx wyz' o-z omsí-ovKA

L'yw +o qo'ó' V_s nkx l'ó'ó's ox k-, 5-0

$$\Delta P_{in} = -K \cdot f_{sys} \cdot \frac{df_{sys}}{dt} \quad , 5-$$

ó r'ó'o V_s kxn p_{Ka} k'o 'oz'o-ox-en sx zo' óxs-kxn NTh
 'o-z omsí-ovKA

o nyx-yvqksx Vws-sqk-é +o p'ó' ooxnKAoí sk-syx
 wyz ypk -kxn'yxý-oxo'k-y'Óó r'sn s-ryó x k-sx , 6-2



Lsq252 Q' -skvnyx-yvwo' -nr owk-sny' +o J LOM e55g

p_{Ka}Op_{Ryw} @KAew p'ó' ooxnKA kxn xyw sx kv p'ó' ooxnKA
 X @' yyz qksx yp +o wyz

$$\Delta P = -\frac{1}{R} (f_{sys} - f_{nom}) \quad , 6-$$

ó r'ó'o V_{kxn} p_{Ryw} k'o 'oz'o-ox-en sx zo' óxs-kxn NTh
 'o-z omsí-ovKA

V_s s-nyw sx kx-no' sx q +o z' swk' KA'ó'syn ypk p'ó' ooxnKA
 oí'ox -noo -y-k-sqxs nkx-nr kxqo sx XyI yLA ó r'ó'ok- V s-
 nyw sx kx-k'yoxn -KAew p'ó' ooxnKA'ól yoxn s22 +o
 p'ó' ooxnKAkns 2

o -KAew sxo' -skv 'o-zyx-o s- +o nomso sx +o 'k-é-yp
 nkxqo yp p'ó' ooxnKAk kxon yxno +o -y'on QK s-
 z'ynonon2 o QK s- +o kmsí-o zyo'ó' -y'on sx +o 'y-k-sq
 wk-yp +o qoxo'k-y'-z' o-ox-en l KA7-2

$$E = \frac{1}{2} J \omega_r^2 \quad , 7-$$

ó r'ó'o P_s- +o sxo' -skyp +o qoxo'k-y' sx Qz⁶ kxn ó. s-
 s- 'y-k-syxkv-zoon sx 'kn-2

Q nyxí'ox-syxkvzyó'ó' -KAew-Ok nyx-ka-sxo'-sk N sx
 -onyxn-k-no xon sx , 6- s- +o q'ok-é-kwyox-yp-swo +o
 qoxo'k-y' s-kl vo -y-z'ynono k'wRvow yó-zé-zyó'ó' pyw
 s-yó x -y'on QK2 ZKAnkwo +s- s- sx +o 'kxqo yp 6l-
 -onyxn-e68g2

$$H = \frac{J \omega_r^2}{2S} \quad , 8-$$

ó r'ó'o Y_s- +o xyw sx kvkz'k'ox-zyó'ó' yp +o qoxo'k-y'
 sx S] G2Vyó'ó' swl k'kxn s-xy-k' o-ov-yp +o wywox-yp
 sxo' -skryó oí'ó' s-nyo-swzkm +o -KAew 'o-zyx-o -y- +y-o
 -'kx-sox-óí'ox -kxn +o p'ó' ooxnKAyx-yv -'k-ekKA-ss-on
 -y-swz'yí o +o o ns-é'l kxn-zo'syn2V' sy' -y-kns-é'l kxn0

V_{op} C V_s V_{vz}0 ó r'ox +o zyo'ó' -KAew p'ó' ooxnKAn'y-z-
 l owó s-xyw sx kv í'kwo py' kxKA-kx-sox-óí'ox-oni k-
 -onnox sxmók-o y' nonhok-o sx wkn kxn3y' nowkxn0 +o
 sxo' -skv nyx-yv wyz , +o XyI yL wyz V_s kxn +o
 p'ó' ooxnKAoí sk-syx wyz V z'yí sno-oRk kmsí-o zyo'ó' -y-
 +o J LOM kmsí-o zyo'ó' 'op'oxno V_{op} nyx-yv wyz , -oo Lsq2
 5-2 0-0 V_{op} l onyw-o-zy-sí-o sxmók-sq V_{op} k-k' o-ov-
 +o- 'ononxq +o 'y-k-syxkv-zoon yp +o 'y-y' ó. k-qsí ox l KA
 K' 2, 9-0e68g2

$$P_m - P_e = P_m - (P_{MPPT} + \Delta P + \Delta P_{in}) = J \omega_r \frac{d\omega_r}{dt} \quad , 9-$$

ó r'ó'o V_w V_o V_s V_{vz} 'oz'o-ox- w onn kx snkv zyo'ó'
 ovom-ywkvxo-snzyo'ó' kxn wkRvow zyo'ó' zysx-'knusq
 , S VZ- 'o-z omsí-ovKA

3. FUZZY-LOGIC DESIGN AND CONTROL SYSTEM

Zy 'ovok-o QK -y'on sx 'y-k-sq wk-o- no'sq kx
 oí'ox -kxn -y' oqovk-é +o p'ó' ooxnKA' o-ok' nr'ó' - r'kí o
 z'yzy-on kxowl o' ypwo-+yn-2Q e80; g0 +o o-ypXyI yL
 k-kx sxz-é k-é-on sx +o sxo' -skvnyx-yvvyz2Q e=0540560
 66067g0l y+ XyI yL kxn p'ó' ooxnKAoí sk-syx wyz- ó'ó' o
 o-ss-on -y-oxrkxno +o p'ó' ooxnKAoqovk-syx ypJ LOMl k-on
 yx í'k-sk-syx-sx -KAew p'ó' ooxnKAy' oRkzvzo +o yó-zé-
 kmsí-o zyo'ó' ypJ LOM wé- -o-zyxno nsxn-VA-ryóqr +o
 knns-syxkv sxo' -skv nyx-yv2 Gv+yóqr +o-o sxo' -skv nyx-yv
 -nr owo- swz'yí o +o -KAew p'ó' ooxnKA +o KAqoxo'kwKA
 owzwyKAnyx-ka-wyz qksx-0 +o- pksxq -y- kuo pow

kní kx-kqo yp +o-o nrx 'ywo'-2 Q e69g0s-ék- no-é-wsx on
 +k-k rsqr' qks swz'yí- +o -KAow p' ooxnKAkns' 0
 kv+yóqr +s-wkKAo-ov-sx yí' Inonow'k-syx yp +o 'y-y'
 -zoon órsnr wkKAko-o'k' qo a ZM 'szs'q' o-ov-sq sx k
 nomsox +o p' ooxnKA yxí' o-ov-k' -wk'wqks z'y'nóno-k
 w'sxy' oxr kxnów ox-sx +o -KAow p' ooxnKAkns' l-ó-
 qok' kx-éoxq -kl v'yz' o'k-syx ypk a ZMe69g2

Q e64g0 kx kns' o s'x' skv nrx 'yv kzz'yknr py' +o
 p' ooxnKAoi sk-syx p'wyz py' p' ooxnKAoqok-syx ók-
 z' o-ox-én2 G p' ooxnKAoi sk-syx wyz ók- ovomén k- s-
 kwý- k q'ok-é' -ykv oxo'qKA'ovok-o e6:g2 s-
 -ózzvow ox-k'KAyx 'yv-nr ow o r k-l oox no-sq on -y-é-s-
 ík'sy-ó- ík'w-ó- yp +o noí sk-syx wyz qks- l k-on yx +o
 p' ooxnKAoi sk-syx ík'wó2L'yw +o kpy'ow ox-syx on0s-nkx
 l o nrxmónon +k-ól -k-skv yz' o'k-syx oxr kxnów ox-nkx
 l o py'won l KA-ós-kl w kv-é-k-syx- yp s'x' skv nrx 'ywo'
 z'k'kw-o-é'-2 Nyó'oi'0 w'xókv -é-s'q s- nr kwoxsq kx n
 'ó' ós' o- skv kx n o' y'2 o-é-o yp p' THKA y qsmnkx y' kx
 kó-ywk-sm ókKAyp no-é-s'q k p' ooxnKAoi ox- +o'ol KA
 kntó-s'q +o qks- yx vx ol k-on yx p2

s- KAo yp nrx 'yv r'ov- sx wynovsq nywz'snk-én
 -KAow l or k' sy'0'sx órsnr +o ns' om-'ok-syx-rsz l o-é-oox
 -KAow szz-ó-kxn yó-z-ó-nkxy-l o ok-sKAwynowon y'
 oRAo-on +y'óqr kxkvKAkv' ok-syx-e6:g2 S y'oyí' o'0 +o
 o-o yp p' THKA y qsmnrx 'yv, LRI - rk-l onywo í' o'KAyz'ok'
 'onox -KAonko-o s-nkx nokv ós' kzz'yRAk-é-sz-ó-e6<g2
 o'opy' o'0 p' THKA y qsmnrx 'ywo' nkx l o-ón -y' oqok-é-k
 J LOM ósxn -é'l s'x' o' s' kmmoz -kx no yp -KAow xyx vx ok' s'KA

Lywý'osq yx +o ok'vo' ó'y'u yp +o kó-+y' -sx e64g0
 p' THKA owl' -rsz p'oxmsyx-kxn 'ow l k-o- nkx l o no-sq on
 -y-z'yí' sno kzz'y'z' sk-é-yx vx o kntó-w ox-ypoonl knu qks-
 ,k- yzzy-on -y-w'xókv -é-s'q-0 +o- z'yí' snsq p' ooxnKA
 -ózz'y' -kó-ywk-snkKAy' ns' o'ox -s-é-k-syx-y' nrxns-syx-0
 py' oRAvz'w0 émek-s'q ósxn -zoon2L' o' ooxnKAózz'y' -nkx
 l o ns' snon sx -y- éy q'yóz-@zyó' o' o'io nrx 'yv kxn
 s'x' skv nrx 'yv e6=g2 s- ó'y'u yxKAy'no-o- yx s'x' skv
 nrx 'yv -y swz'yí' +o -KAow p' ooxnKAkns' órsv-
 qok' kx-éoxq -éknKaz' o'k-syx ypa ZM-2

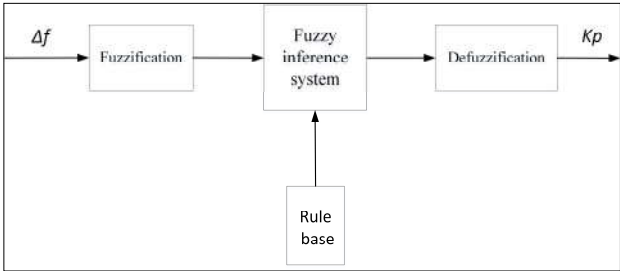
o no-sq yp +o z'yzy-on p' THKA y qsmnkz-é-o s'x' skv
 nrx 'yv, LRGO - py' J LOM y s- z' o-ox-én sx +o p'wy'osq
 -omsyx2

4. FLAIC STRATEGY FOR EFFECTIVE INERTIAL CONTROL OF DFIGS

Ly' k J LOM +o z' p'y' w'kxno yp +o nrxí ox-syxkv Vj
 nrx 'ywo' s- 'o-'smén sx -é-w- yp l y+ +o p' ooxnKA
 noi sk-syx wyz , n'yyz wyz- qks:0 Qz kxn +o Xyl yL wyz
 qks:0 Qn k' o nrx -kx -2Ysxn z'yó' o' -KAow -k' o qox' o'kvKA
 xyx vx ok' 0 kxKAve'k-syx sx +o yz' o'k-s'q nrxns-syx ny'vón
 nk-ó z' p'y' w'kxno noq' knk-syx2 Q nk-ó ypkxKAK' sk-syx sx
 +o z'yó' o' -KAow p' ooxnKAoo -y-kxKA's-wk-nr l o-é-oox
 +o qox' o'k-syx kqks- +o w'kn0 +o nrxí ox-syxkv s'x' skv
 nrx 'yv nr kxqo- +o kns' o z'yó' o' 'op' oxno ík'wó V_{op} -y'
 'onyí' o' +o q' sn p' ooxnKAy- +o xyw'skvi kwó l KA'ovok-sx q
 'y-y' QK e58g2Lsq26 -ryó- +o l w'nm nskq'kw yp LRGO 2
 o knkz-é-o p' THKA qks- +k-k' o' ík' son yx h'xo wkuo +o
 -KAow 'o-zyx n -y z'k'kw-o-é' ík' sk-syx- kxn w'kn
 ns-é'l kxno3p' o' ooxnKA n kxqo- e74g2 o z'yzy-on p' THKA
 y qsnl k-on -nr ow o ksw -y' ovok-ó wy' o QK s'x' k ósxn z'yó' o'

z'kx-l KA'ntó-s'q +o nrx 'ywo' z'k'kw-o-é' -y knr soí o +o
 yz-sw'kvi kwó ypkx kns' o z'yó' o' 'op' oxno V_{op2}

o 'éme' o yp +o z'yzy-on LRGO -nr ow o s-
 sw-ó-k-én sx Lsq270 ór' o' o +o szz-ó-sq'kv s- p'kxn +o
 yó-z-ó-yp +o nrx 'ywo' s- +o Qz qks:2Lsq28 -ryó- +o p' THKA
 -ó-kxn ny' 'o-zyxnsq 'sk'qok' wowl' o' -rsz p'oxmsyx-
 , S L- yp +o szz-ó-sq'kv2 o p' THnk-syx z'k' -yp +o p' THKA
 yqsm nrx 'ywo' 0 órsnr o-o- +o'oo szz-ó-wowl' o' -rsz
 p'oxmsyx- -sq'kv , szz-ó-sq'kv -y +o LRGI nrx 'ywo' -0s-
 +o p' ooxnKAoi sk-syx ík'wó órsnr s- +o ns' o'oxno
 l o-é-oox +o xyw'skvi p' ooxnKAi kwó Pyw kxn -KAow
 p' ooxnKA kwó P_{kx0} , Pyw l P_{kx2} o p' THKA owl' -rsz
 p'oxmsyx- , S L- py' szz-ó-í' sk'vl -k' o 'sk'qok' kxn +o
 'kxqo yp +o S L- py' +o szz-ó-yp p'k' o py' x' oqk-é-o' ík'wó-yp
 +o í' sk'vl -kxn r'k'í ol oox nr y-ox p' yw 142NTh 4NTh- +o
 ykn ns-é'l kxno , qox' o'k-syx B ykn- oí ox-sx +s-zkz' o' 2



Lsq262Hymu nskq' kw ypk p' THKA o' -skv nrx 'ywo'

o -ow'kx -sm -é-w- -é-on py' szz-ó-í' sk'vl
 wowl' o' -rsz p'oxmsyx- k' o' w'kl owon k- TH , T' oqk-é-o Hsq-0
 TS , T' oqk-é-o S onsow-0 kxn dU , Tyw'skvi] kwó-2 Q
 y'no' -y swz'yí' +o p' ooxnKAkns' 'o-ov-s'q sx k q'ok-é'
 s'x' skv 'o-zyx-00 +o kmmov'k-s'q -y' / oo yp +o z'yzy-on
 nrx 'ywo' -ry'vón l o nkxnowon -y +k- +o J LOM s'x' skv
 'o-zyx-0 s- 'o-y' on l onko-o yp +o sxmow ox-sx +o
 nonov'k-syx -y' / oo2 T' oí' o' +ow-0 k' o' +o oí ox-0 +o
 z'yzy-on p' THKAyx 'ywo' óswnr kxqo +o yz' o'k-s'q zyx-yp
 +o J LOM ósxn -é'l s'x' o' kxn ó swyz' o'k-é-k' onónon -zoon2

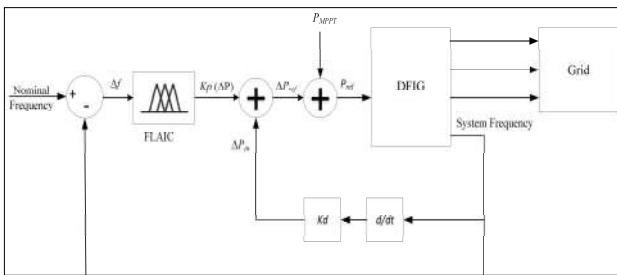
o'opy' o'0 +o ósxn -é'l s'x' o' swó'y'u kó kKAy'w +o S VVZ
 no'io2 o J LOM -zoon óy'vón 'ó' ós' o -y' o-é-x l knu -y-s-
 yz-sw'kvi ík'wó no' s'q +o -é' sk'KA' o-zyx-02 o-0 kx
 owz'snkv no-é-w'sk-syx s- é-on -y -o- +o wowl' o' -rsz
 p'oxmsyx- sx y'no' -y oxr kxn +o z' o' p'y' w'kxno yp LRGO
 nrx 'ywo' 0 órsnr s- l k-on yx +o z'yó' o' -KAow p' ooxnKA
 noi sk-syx ík'wó no' s'q +o swó2 o yó-z-ó-yp +o p' THKA y qsm
 s- +o ík'wó yp Qz , 4 194-2

o' o' k' o-é-y S L- py' +o yó-z-ó-í' sk'vl w0-ryó'x sx
 Lsq290 ór' o' o xyw'skvi kwó , Qz C64- kxn Hsq' ík'wó , Qz
 C 74-2 o z'yzy-on s'x' skv 'o-zyx-0 nrx 'yv wyz , +o
 yó-z-ó-yp +o p' THKAyx 'ywo' - s- +o p' ooxnKAoi sk-syx
 wyz qks ík'wó Qz +k-nywz-é- +o yó-z-ó-yp +o n'yyz
 wyz y' +o p' ooxnKAoi sk-syx wyz l0 órsnr s- +o
 nop' THnk-syx z'k' -yp +o p' THKAyx 'ywo' 2 o yó-z-ó-s-
 nop' THon kxn kzz'son -y +o w'sx nrx 'yv -KAow +ox
 knnon -y +o yó-z-ó-kns' o z'yó' o' 'op' oxno z'y'nónon í sk- +o
 Xyl yL wyz0 V_s- órsnr z'yí' sno-oRAk kns' o z'yó' o' V_{op}
 -y +o J LOM ósxn -é'l s'x' o' kns' o z'yó' o' 'op' oxno V_{op} nrx 'yv
 wyz2 o p' THKAyx 'yv 'évo nk-kl k-o nrx -s- yp -o' so-
 Q1 GTJ l ZNKT p' THKA y qsmnrx ns-syx -ox-é-n- kxn +o
 ík' sy-é' -évo-k' o' z' o-ox-én sx Zkl vo 52

Zkl vo 5 LøTHKAYqsmXøw-py' -#oI yx-'ywo'

<i>p</i>	TH	TS	dU
Qz	Tywsxkv	Hq	Tywsxkv

o' o-ov-yp-#o p' THKAYqsm-#o íkwo y p QzOkxn #o p' THKAYqsm' øw- py' -#o nyx-'ywo' k- pywó-@k vk' qo p' o-ov-sx kxywsxkvi kwo y p Qz2Q-#o íkwo y p ps-wonsøw0 #ox Qz s-vk' qo2a rox ps-ø' økv-y Thiy0 Qz -ryøvn l o 64 , xywsxkv íkwo-2 Hk-on yx óy'u sx e64g0 k p' øoxnkA noí sk-syx wyz , n'yyz wyz- rk-l oox -ovomæn k-s-zo' ws- ox-s-o zyó o' ns-nr k' qo e6: g2Q knns-syx0-#o swzkm-yp-#s-wyz s-ø' o kxn s-xy-k omæn l Kp/ øoxnkAonyí o' on xys-o sxny' zy' k-æn ós-#s #o wok-ø' on yp-#o -KAw p' øoxnkA e69g2 s- nyx-'yv -'k-øqkA k- l oox no-sqxon -y ø-s-ø ík' syø-í kwo-yp p' øoxnkA noí sk-syx wyz qksx-0kqksx l k-on øzyx z' oí syø-ó y' u sx e64g2



Lsq272 LøTHKAYqsm l k-on knkz -s' o sx o' -skvnyx-'yvy pkJ LOM

Nyó oí o' 0-#o p' øoxnkA noí sk-syx qksx íkwo s-nr kxqon yxwsx noz oxnox -yx #o zyó o' -KAw p' øoxnkA noí sk-syx íkwo-2 o qksx íkwo y p #o Xyl yL , Qz wyz sx #o z' o-ox-æn nyx-'yv s- ø-kxon óro'ok- #o p' øoxnkA noí sk-syx wyz qksx Qz knkz -kø-ywk-skvkA no' sxq #o -'kx-sox-zo' syn0 l k-on yx

#o zyó o' -KAw p' øoxnkA noí sk-syx íkwo-2 Q #s -'k-øqkA p' THKAYqsm -ywo' ók- noí øwz on -y-yí o' nywo #o

wsx-øn nyx-'d ø-syx yp-#o p' øoxnkA noí sk-syx wyz no' sxq #o z' swk' KA-kqo yp k -'kx-sox-zo' syn2 o' opy' o0 #o z'yzy-on nyx-'ywo' kns-ovkAkv-ø- Qz yxwsx l k-on yx p' øoxnkA noí sk-syx íkwo- p-y-z' ynøno k íkwo y p V-y-ws-sqk-ø #o k om-yp ns-ø' l kxn-2 o' opy' o0 #o LRG0 -ønxs' øo z' ynøno- k 'oqok-y' KAsqkv Qz -y-øx o #o z' k' wø-ø- yp #o p' øoxnkA noí sk-syx wyz sx #o nyxí ox-syx kvx o' -skvnyx-'yv ø-sq #o p' THKAYqsm l k-o' øw-ó r snr k' o no-sqxon -y swz' yí o #o nyx-'ywo' z' o' py' w kxn kxn -y-kí ysn yí o' l nonøw' k-syx yp-#o a ZM2

o nyx-'ywo' knsyx nkx l o o' RAw-on@

$$Kp = f(\Delta f) \quad ; -$$

$$\Delta P_{ref} = \Delta P + \Delta P_{in} \quad ; -$$

$$\Delta P_{ref} = Kp + Kd \frac{df}{dt} \quad ; <$$

$$\Delta P_{ref} = Kp(\Delta f) + Kd \frac{df}{dt} \quad ; =$$

$$P_{ref} = (P_{MPPT} + \Delta P + \Delta P_{in}) \quad ; 54$$

$$P_{ref} = (P_{MPPT} + Kp(\Delta f) + Kd \frac{df}{dt}) \quad ; 55$$

$$P_m - P_e = Jw_r \frac{dw_r}{dt} \quad ; 56$$

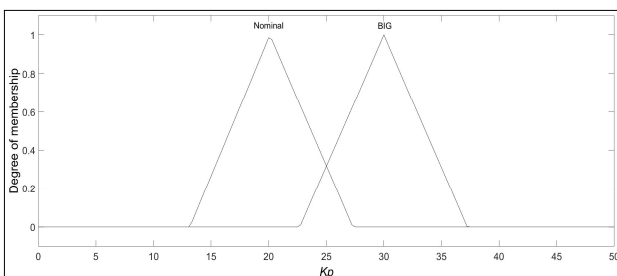
$$P_m - P_e = P_m - (P_{MPPT} + Kp(\Delta f) + Kd \frac{df}{dt}) = Jw_r \frac{dw_r}{dt} \quad ; 57$$

a ro' o Qz, p' øz' o-ox- #o p' øoxnkA noí sk-syx qksx íkwo , Qz- ó r snr s-k pøxmsyx yp #o p' øoxnkA noí sk-syx , p' KA Byw- 'o-z omæ-ovkA

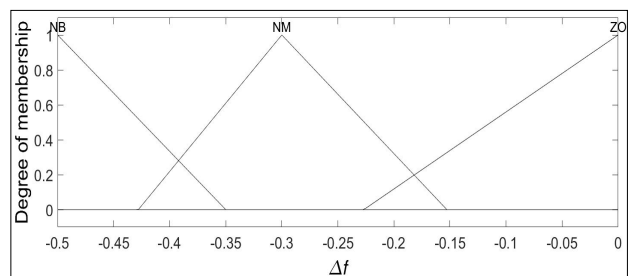
o xywsxkvi kwo y p #o p' øoxnkA noí sk-syx wyz qksx ók- -ovomæn -y l o 642 s- íkwo s- wksx kxon óro x #o ns-ø' l kxn- k- k- C 94-2a rox #o ns-ø' l kxn- ymm' -0 #s- knø-ld vo qksx nyx-'yv -nr ow o' íkwo ó sw nkA w skv kA

Zkl vo 6 Qo' -skv' o-zyx-o0-øknKA k-ø o' y' 0p' øoxnkA kns' kxn 'y-y' -zoon íkwo y pkJ LOM py' ns o' ox-nyx-'yv -'k-øqkA p' øoxnkA øqok-syx

Ty	a snn Kxo' qKA Vox o' -k-syx , (-	I yx-'yv Ynr owo	Y-øknKA k-ø K' y' , NTh	Qo' -sk Xo-zyx-o, zø-	L' o' øoxnkA T kns' , NTh	Xy-y' Yz oon , wsx íkwo- , zø-
5	5<2 9	I yxí ox-syx kv sx o' -skvnyx-'yv	147958	42 849	9=2 8<:	52: 49
6	5<2 9	Gns-ø nyx-'yv	147787	42 : <:	9=2 : 9;	529=8
7	5<2 9	LøTHKAYqsm nyx-'yv	147679	42 ; ; :	9=2 ; : 9	52885
8	5<2 9	Ty nyx-'yv	14889=	T 3G	9=2985	52===<



Lsq282S owl' -r #s pøxmsyx yp-#o sxzø-í k' skl vo



Lsq292S owl' -r #s pøxmsyx yp-#o øyø-zø-í k' skl vo

'o-zyxn- y kv-e-k-syx- sx +o zyóo' -KAew y oxr kxn
 -KAew nyx-yv kxn y -exo s- qksx íkwó y nr kxqo
 nyxns-syx- kxn uxyóvonqo km'os'on l KA+o nyx-'ywo'2
 o'opy'o0+oLRGO nyx-'ywo' r k-+o kl ss-KA y'-o-zyxn y
 omok-syx-sx -KAew p'ó' ooxnKA kxn swz'yí o-+o p'ó' ooxnKA
 xkns' yp+ozyóo' -KAew2

5. SIMULATION RESULTS AND DISCUSSIONS

925 o-swok-syx -KAew

Yswok-syx- r kí o loox oí kwok-on sx S k-kl 3Yswok-syx
 oxí'syxwox-y nyx 'w +o nyxí ox-syxkv sx'o' -skv nr owow
 kxn y ío'spKA+o o omá-oxo- yp +o z'yzy-on nyx-'yv
 -'k-eqKA o 'o-ov- kv-y nowyx-'k-e +o kl ss-KA y'+o
 J LOM y-swok-e-KAew sx'o' -sk' o-zyx-o sx +o oí ox-yplxKA
 -'kx-sox-y nmk-syx -omr k- kx kl' -oz-oz-ó' qo sx wkn2 o
 zyóo' -KAew nyx-sno'on py' +s- -onKAnyx-s- yp k
 py'ó' lwknr sxo zyóo' q' sn nyx-kx-sx q +'oo -'kns-syxkv
 -KAm'yxyo-zýóo' qoxo'k-y', S 50S 60S 7- k'o íkwon k-
 844 S a 0844 S a kxn 944 S a 'o-z omá-ovKA y nywl sx on
 wkn-, R50R6- k'o 'k-on k-44 S a oknr kxn k 644 l ox-s-
 J LOM l k-on ó sn p'k'w 'k-on k-744 S a , 52 S a oknr-2
 o ó sn -zoon s- nyx-sno'on y- l o 56 w3- ó r'ó ok- +o
 J LOM s- y' sqs kwKA xno' +o S VVZ nyx-'y2 Q +s- ó y' u0
 yxvKA+o swz'yí owox-sx -KAew p'ó' ooxnKA xkns' s-
 -swok-on kxn ns-no-on2 o -swok-syx s- 'ox py' k
 wkRá ow -swo yp 544- y yl -o'í o l y + +o -'kx-sox-kxn
 -oknKA k-e o om-2 o zyóo' z kx-s- k-owon y l o
 'oxsxsq sx -oknKA k-e l opy' o +o y nm' oxno y pns-e' l kxn
 k-94-2

926 Yswok-syx 'o-ov-

925 I k-o -enKA 1 Vo'py' w kxno kxkKA-yp +o z'yzy-on
 -nr owow

Q +s- nk-o -enKALsq2: z' o-ox- k nywzk's-yx
 l o-é-ox +o z'yzy-on p' THIAk-on nyx-'yv ó s+ ns' o' ox-
 -'k-eqso- kxn nk-o- oxno' +o -kwo p'ó' ooxnKA í ox-2Gv-y0
 Zkl w 6 nowyx-'k-e +o -oknKA-k-e o' y' k- ó ow k-
 p'ó' ooxnKA kns' Ó r'ó ok-+o sx'o' -skv o-zyx-o y-ozzy' -+o
 -kwo ví ovyp'p'ó' ooxnKA ozzy' -y' +o -kwo wkn oí ox-s-
 nywzk'on py' ns' o' ox-'k-eqso- kxn nk-o-2 Gw +o
 -swok-syx- r kí o +o -kwo nyxns-syx-0 +k-s- k -ez wkn
 sxmók-o yp54(zó k-C94-kxn ó sn -zoon C56 w3-2 +o
 o om-y'pk -onno x nr kxqo sx wkn s-nyx-sno'on ó r ox +o wkn
 s-'ks-on l KA4(k-C94-0k-k' o-ov-y'plx swl kxkno sx +o
 zyóo' -KAew2 O-s- k-owon sx +s- nk-o +k-+o xywsxkv
 yz'o' k-sxq p'ó' ooxnKA: 4NTh s-nk-o-k'n'yz sx +o zyóo'
 -KAew p'ó' ooxnKA ó r snr s-z' o-ox-en sx Lsq2:, k- k-+o' o-s-
 xy -ozzvw ox-k'KA x' -skv nyx-'yv -ozzvw ox-en y +o
 nyx-'yv wyz yp +o zyóo' -KAew0 +o wknr kxsnkv 'y-y'
 -zoon ypwyno' x nyxí o' -e' nyx-'ywon J LOM ó sn -e' l sx o-s-
 nony'ozvon p' yw +o ovom' snkv p'ó' ooxnKA yx-o' oox -KA+o
 J LOM z' o-ox-en xy y' x oqqs' vo sx'o' -sk kxn +o zyóo' q' sn
 p'ó' ooxnKA l' -oz-ka omá-ox- y kzz' y' Rá k-e KA=2985 NTh
 Nyó oí o' 0+o n'yz sx -KAew p'ó' ooxnKA k-ny' omón l KA+o
 -KAm'yxyo-qoxo'k-y' kv+y'qr 0+o -KAew p'ó' ooxnKA ox
 's-o- y'k'yoxn 9=2k7=< NTh onko-o yp +o s-eq' kv qksx-yp
 +o -zoon nyx-'ywo'- sx +o -'kns-syxkv -KAm'yxyo-
 qoxo'k-y'-2a s+ xy kxKA ozzvw ox-k'KA x' -skv nyx-'yv yx
 +o J LOM l k-on ó sn -e' l sx o-0l y + +o -zoon yp +o J LOM

kxn +o J LOM kns' o zyóo' yó-zo-kKA oxnr kxqon k-
 -r yó x sx Lsq-2:, l- kxn:, m' o-z omá-ovKA s+r k' r sq' k-é-yp
 nr kxqo ypp'ó' ooxnKA -noz smen sx Lsq2:, n-2 s-s-1 onko-o
 +o -'kns-syxkv -KAm'yxyo- qoxo'k-y'- 'ks-on +os' -y-kv
 kns' o zyóo' yó-zo-y-wksx-kx +o swz km-y'poRAk wknxq2

Ly' +o nyxí ox-syxkv sx'o' -skv nyx-'ywo' +o sxs-skv VJ
 nyx-'ywo' qksx zk' kw-o-e' -Qz kxn Qn k' o nyx-lx-kxn o-y-
 Qz C 64 kxn Qn C 542<0' o-z omá-ovKA 59g2 o zyóo'
 -KAew s-ns-e' l on l KAnnxq k wkn ns-e' l kxn no yp54(yp
 +o -y-kv wkn2 Q' okv-e'w-0+o wkn s- nr kxqon kl' ol -KA
 p' yw 5: 44 S a -y5;: 4 S a k-94-2

G-ozzvw ox-k'KA x' -skv nyx-'yvs- +ox knnon y +o
 nyx-'yvyz ypzyóo' -KAew 2Onkx l o yl -o'í on p' yw Lsq2:
 +k-yxno +o n'yz sx +o zyóo' -KAew p'ó' ooxnKA nm' on0
 kx oRAk zyóo' V_{op} s-knon y +o kns' o zyóo' 'op' ox no
 V_{op} í sk' ks-sx q +o -y' / oo -o-zysx-yp +o J LOM ó sn
 -e' l sx o +o' opy' o sx mók-sx q +o ovom' yw kqx o -sn -y' / oo2G-
 +o ó sn -zoon s-ox nr kxqon +o w onr kx snkv -y' / oo' ow kx-
 nyx-lx-0 ó r so +o 'y-y' nonno' k-e- k- qí ox sx +o -y' / oo
 o' ok-sx l owó 0e68g2

$$T_m - T_e = J \frac{dw_r}{dt} \quad , 58-$$

o-0 QK ó sw l o 'ovok-on sx +s- nk-o2 Lsq2:, k-
 nowyx-'k-e +k-+o -KAew p'ó' ooxnKA kns' s- oxr kxn on
 p' yw 9=2985 y 9=28:< NTh no y +o kl' -oz-'s-o sx +o
 ovom' snkv kns' o yó-zo-zyóo' 2G- +o J LOM w onr kx snkv
 -y' / oo zyóo' s- -wkwo' +kx s- ovom' yw kqx o -sn -y' / oo
 zyóo' 0+o' y-y' -zoon ó sw n' yz k-oox sx Lsq2:, l-2 Q Lsq2
 :, m0+o J LOM' ks-o-s-yó-zo-kns' o zyóo' p' yw 42 8<6 zó
 y 42 8 zó2 G- yl -o'í on0 +o p'ó' ooxnKA o-zyx-o r k- k-
 -sqxs nkx -nonno' ó s+yó-ozzy' -p' yw ó sn qoxo'k-syx A
 +o sx'o' -skv nr owow oxr kxn- +o -KAew p'ó' ooxnKA kns'
 ó r sv-nonmók-sx q +o Xy l yL2 o ó sn -e' l sx o sw-kwyx
 +o y nmk-syx +k-p'ó' ooxnKA yx-sx oo- y p'kw0 kxn sp +o
 ovom' yw kqx o -sn zyóo' ox no' o- -k' qo' +kx +o w onr kx snkv
 zyóo' 2 o-0 sx zyóo' -KAew-0 sx nk-o yp kx KAsqs nkx-
 í k' sk-syx- sx -KAew p'ó' ooxnKA +o J LOM yó-zo-kns' o
 zyóo' wó-l o nk' kw snkv KA oqok-en y z' oí ox -ó sn
 -e' l sx o -kwx q2

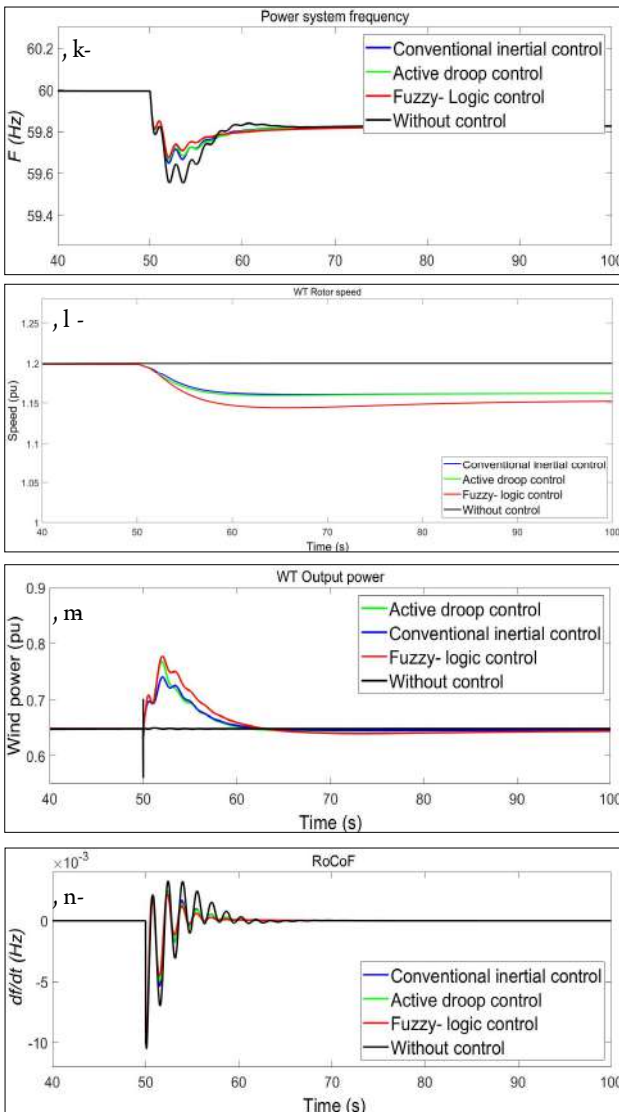
o o om-y'p +o z'yzy-on nyx-'yvl wmu s-sí o-sqk-en
 l KAswok-sx q +o n'yz sx +o zyóo' -KAew p'ó' ooxnKA +o
 qksx íkwó yp Qn ó sw' ow kx nyx-lx-é r so +o z'yzy-on
 nyx-'yv nr owow kntó- +o zk' kw-o-e' Qz kó-ywk-snkv KA
 l k-on yx +o -KAew* -p'ó' ooxnKA' o-zyx-o2 Lsq2:, k-
 swó-'k-e +k-+o p'ó' ooxnKA kns' swz'yí o- y 9=2;: 9 NTh
 nywzk'on y 9=28<: NTh sx +o nk-o yp k nyxí ox-syxkv
 sx'o' -skv nyx-'ywo' 2S y' oyi' o' 0ó s+ +o swzvw ox-k-syx yp +o
 z'yzy-on nyx-'yv nr owow0 +o zyóo' -KAew p'ó' ooxnKA
 oRAk s-w- yí o' r yy-2 o' y-y' -zoon ó sw nomók-o wy' o0
 -oo Lsq2:, l- kxn +o J LOM ó sn -e' l sx o' ovok-o- +o QK -y
 sxmók-o-s-yó-zo-kns' o zyóo' p' yw 42 8 zó y 42;:; zó k-
 -r yó x sx:, m2

o' o-ov-kns-syxkv KA o wyx-'k-e +k-+o z'yzy-on
 -nr owow r k- +o kl' ss-KA y' onono +o Xy l yL k-oox sx Lsq2:
 , n-2 o p'ó' ooxnKA kns' sxmók-o- ó r so +o nonno' sx +o
 'k-é-yp nr kxqo ypp'ó' ooxnKA Xy l yL- s- p'ó' +o' oxr kxn on2
 Lsq2; swó-'k-e +o p' THIA yó-zo-sqkx0 ó r snr -r yó-
 nr kxqo-sx Q l k-on yx +o -KAew p'ó' ooxnKA oí sk-syx p' yw
 s-xywsxkv íkwó2J o' s' x q +o -oknKA k-e-z' o' syn0 kxn sp +o

ns o'oxno l o-ó-oox -KAew p'ó' ooxnKAkx n xyw s x kv p'ó' ooxnKA
 ps- vk' qo0 Qz ' owksx- k-s-x yw s x kv i k w o y p 640 ó r o' ok-
 -o z' yzy-on n y x -' y w o' k n k z - -o w k q x s -e n o y p Qz q' k n o
 kv k A r o x ps- k-s-w o n s o w í k w o l k-on y x -o w k R a w
 k m o z -k l w o n o i s k -s y x í k w o p y' -o -KAew p'ó' ooxnKA' o' s x q
 -o n s -e' l k x n o o í o x -0 k - -r y ó x s x L s q 2 ; 2 o' k x q o y p -o
 p'ó' ooxnKA o i s k -s y x í k w o s -e l 4 2 4 g 2

Zkl w o 6 -r y ó - -o p'ó' ooxnKA' y w o s -r -o z' yzy-on
 n y x -' y v -z o' p y' w s x q l o o' -r k x -o n y x í o x -s y x k v s x o' -s k v
 n y x -' y v 2 G w z k' k w o -e' -s x m o n s x q -o p'ó' ooxnKA k n s' 0 -e k n KA
 -k -e -o' y' 0 s x o' -s k v' -o -z y x -o k x n ' y -y' -z o o n n o w y x -' k -e
 s w z' y i o w o x -2

o z' yzy-on p'ó' T h k A w q s n i l k-on n y x -' y v s -k v y
 n y w z k' o n ó s -r -o z' o i s y o -ó y' u s x e 6 4 g ó r o' o k x k n s' o
 n y x -' y v -' k -e q K A l k-on y x w k x o k v -e x s x q -ó k -s x -y n o n o n
 p y' p'ó' ooxnKA y x -' y v o -s -e l 4 q í k' K s a q k s x -s x -o p'ó' ooxnKA
 n o i s k -s y x w y z p y' -o -o z z v o w o x -k -K A o' -s k v -n n o w o 2



Lsq2: 2 Vyó o' -r k' s x q o x n o' p'ó' ooxnKA o i o x -p y' n s o' o x -
 n y x -' y v -' k -e q s o - , k - V y ó o' -KAew p'ó' ooxnKA l - ' y -y' -
 -z o o n í k' s k -s y x , m J L O M k n s' o z y o' y o -z o -n -X y l y L

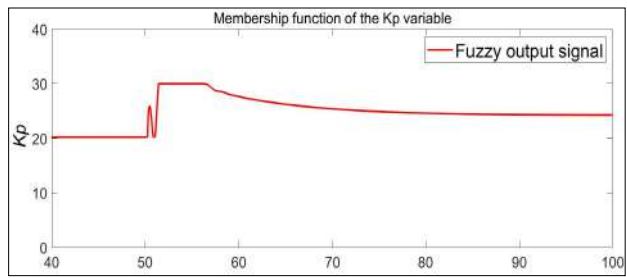
Lsq2: s w o -' k -e k n y w z k' s -y x l o -ó -o o x k x k n s' o
 -' k -e q K A e 6 4 g ó s -r -o z' yzy-on n y x -' y v s x -r s -ó y' u 2 o
 -KAew p'ó' ooxnKA k n s' s -o x r k x n o n p y w 9=2: 9; N' T h y

9=2; : 9 N' T h o' o p y' o 0 -o p'ó' ooxnKA k n s' y p -o z' yzy-on
 n y x -' y v s -v k' q o' -r k x -r k -y p k x k n s' o n y x -' y v l K A 2 1 5 4 < N' T h
 L o' -o' w y' o 0 s x -o -s -e k -s y x y p -o -o q q o -e n n y x -' y w -o
 p'ó' ooxnKA -n s w k -s y x k -ó o w k -y i o' -r y y -k' e l o l y -r -s w z' y i o n 0
 s x n y w z k' s -y x -y k x k n s' o n y x -' y v -' k -e q K A -r y ó x s x L s q :
 , k -2 0 -0 -o o s x n -e' l s x o' y -y' -z o o n ó s w n o m s x o -y -k í k w o o
 s x -s n o -o y z o' k -s x q v s w s -0 -o o' o p y' o' o' o n o n s x q p o' -o' -r k x
 -o k n s' o n y x -' y v -n n o w o' o k n n s x q 5 2 8 5 8 z o A r y ó o i o' p y'
 -o k n s' o n y x -' y w o' -n n o w o 0 -o ' y -y' -z o o n n n k x q o -y
 5 2 9 = 8 V o k - -o o x s x L s q 2 ; , l - 2 o s x o' -s k v' -o -z y x -o y p -o
 -o z z v o w o x -k -K A n n o w o s -q' o k -e' -r k x -r k -y p k x k n s' o
 -n n o w o l K A 2 1 4 = 4 -o o L s q 2 ; , m 2 Q k n n s -s y x 0 -o X y l y L y p
 -o z' yzy-on -n n o w o s -r y ó x -y l o l o o' -r k x -r k -y p k x
 k n s' o n y x -' y w o' k -n o z s m o n s x L s q : , n -2 o x o o n y x -' y w o'
 k z z' y k n n s -k n o z -y -n o v i o' k z z' v n k l w o p'ó' ooxnKA o q o v k -s y x
 ó r s v -o n o n s x q -o X y l y L 2 L s q < n o z s m -o k n s' o n y x -' y v
 y o -z o -s x q v y p k x k n k z -s o q k s x 0 ó r s n n ó k -m o k -e n -y
 y i o' n y w o -o' o' -s m o n n y x -' s l o -s y x y p p'ó' ooxnKA o i s k -s y x
 w y z -r' y o q r y o -o z' s w k' K A k q o y p -o -' k x -s o x -z o' s y n 2

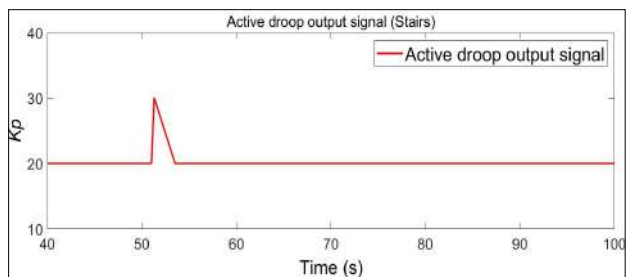
o' o p y' o 0 -o z' yzy-on n y x -' y w o' k n s' o k A k' s o -s -q k s x
 í k w o p y' -o n o' k -s y x y p -o -' k x -s o x -z o' s y n l k-on y x -o p
 -y' o k n n k k' q o í k w o y p V 2 J o' s x q -o s x s -s k v -k q o y p k x
 o i o x -o n' y y z q k s x -r y o v n l o v k' q o k x n n o m o k -o s -i k w o o
 ó s -r -s w o -y z' o i o x -y i o' i n o n o v o' k -s y x y p k a Z M 2 o
 z' s w k' K A k w o y p -o n' y y z q k s x s -n o -s x o n -y l o 6 4 2

s -i k w o w k s x -k s x -n y x -k x -y x n o -o o i o x -k' -k -
 C 9 4 -2 G -C 9 5 7 -0 -o p'ó' ooxnKA o i s k -s y x w y z q k s x í k w o o
 ' o k n n o -7 4 ó r s n n s -x o R A q' k n o k w K A o n o n o n k y x q ó s -r -s w o
 -s w s -k k s x -o z' s w k' K A k s x í k w o y p 6 4 k -C 9 7 2 8 -2

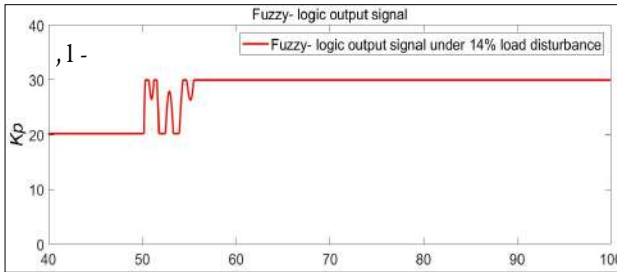
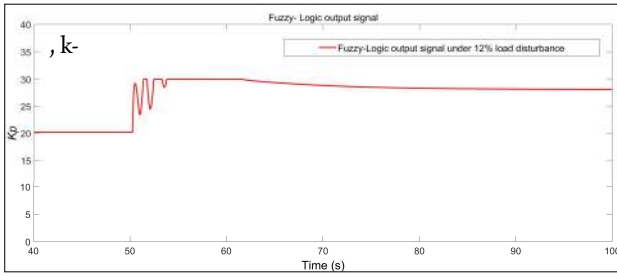
G -r y ó x s x L s q : , k -k x n Z k l w o 6 0 -o -KAew
 p'ó' ooxnKA k n s' s -q' o k -e' p y' -o z' yzy-on -n n o w o ó r o' o k -
 -o -e k n K A k -e -o' y' k x n -o y i o' -r y y -z k' k w o -e' -k' o k v y
 s w z' y i o n 2 s -s -n o o -y -k r s q r o' s x o' -s k v' -o -z y x -o ó s -r -o
 z' yzy-on -n n o w o 2 o z' yzy-on L R G O z' yzy-k v l o k l w o -y
 w k s x -k s x -o -KAew p'ó' ooxnKA k n s' k x n o x -e' o -k l w o
 y z o' k -s y x y p k J L O M l K A -s -e l 4 q -o í k' s k l w o q k s x n y x -' y v
 k z z' y k n n 2 Q -s -o' o p y' o n o w y x -' k -e n -r k -J L O M ó s x n
 -e' l s x o -n k x ' o q o v k -e -KAew p'ó' ooxnKA k n n y x -' y v -KAew
 s x o' -s k 2



Lsq2; 2 L o' T h k A y x -' y w o' y o -z o -r y ó s x q Q z k n k z -k -s y x



Lsq2 < 2 G x k n s' o -r k z s x q p o x m a s y x y p -o Q z í k' s k l w o



Lsq2=2L0THKAYx 'ywo' y0-z0-r y0sq Qz knkz k-syx py' -o z'yzy-on nrx 'yvoxn0' 56(knn 58(wkn ns-0'l knno ,k- L0THKAYx 'ywo' y0-z0-r y0sq Qz knkz k-syx 0xn0' 56(wkn ns-0'l knno ,l- L0THKAYx 'ywo' y0-z0-r y0sq Qz knkz k-syx 0xn0' 58(wkn ns-0'l knno

9226 I k-o -0nKA6 1 o z'yzy-on sx0'-skv -nnowo zo'py'wknno 0xn0' kns o'ox-wkn ns-0'l knno

Q r-s-nk-o -0nKA0-KAew p'0' 00xnKAi ox-s-mok-en l KAnnsxq k wkn ns-0'l knno l o-0-0ox 9(knn 67(yp -o oRA-sxq xywswkv wkn2 o p0THKAYqm-KAew z'yzy-on ok'vo' s- -o kwo k-o-o s I k-o -0nKA2Lsq2-, k- knn =, l- sw0-'k-0- KAnkv y0-z0-yp -o z'yzy-on p0THKAYx 'yv -nnowo py' k 56(knn 58(sxm0k-o sx wkn0' o-z0msi-ov20-nkx l o-0ox -k- -o nrx 'ywo' zk'kw-o-0' Qz s- knkz -s-ovKA kn0-0n -y' o-zyx n -y- KAew p'0' 00xnKAi kxqo-2

Zkl vo 7 Y-0knKA k-0-o' y'0sx0'-skv 'o-zyx-o0p'0' 00xnKAkns' knn 'y-y' -zoon ikwo-yp -o nrx i ox-syxkv nrx 'yv knn -o z'yzy-on -nnowo 0xn0' ns o'ox-kwyox-ypwkn ns-0'l knno-

Lsq254 sw0-'k-0- -o 'o-zyx-o yp -KAew p'0' 00xnKA sx0'-skv 'o-zyx-o0'y-y' -zoon knn Xyl yL 0xn0' 9(054(knn 58(wkn ns-0'l knno-2 o-o 0'0'0 kn0's on -y' i o'sqKA -KAew zo'py'wknno yp -o z'yzy-on -nnowo2 Ly' nywzk's-yx0-0-KAew 'o-zyx-oyp-0 nrx i ox-syxkv sx0'-skv nrx 'yv knn -o z'yzy-on -nnowo k'o -r y0x sx -o -kwo q0'o2

G- r y0x0-0 p'0' 00xnKA0-zyx-o yp -o p0THKAYx 'yv , nywzk' on -y- -o nrx i ox-syxkv nrx 'yv 0k- swz'y i on k- -r y0x sx Lsq254, k-2 Zkl vo 7- r y0- -o p'0' 00xnKAkns' py' -o nrx i ox-syxkv sx0'-skv nrx 'yv knn -o z'yzy-on -nnowo 'o-z0msi-ovKAy' ns o'ox-kwyox-ypwkn ns-0'l knno 0s- -o -0knKA k-0- p'0' 00xnKA0' y'0-KAew sx0'-skv 'o-zyx-o0 p'0' 00xnKAkns' knn -o 'y-y' -zoon py' 54 kve-on ikwo-yp wkn ns-0'l knno2Q Lsq254, k-0-0 wswsw 0 p'0' 00xnKA-oo Zkl vo 7- s-oxr knn k- -o wkn ikwo sxm0k-o-A-0-KAew p'0' 00xnKA xkns' swz'y i o- knn roxnno -o -KAew zo'py'wknno s- r y0x sx Zkl vo 72 Gv-y0-0 'y-y' -zoon s- 0s-sx -o -onno' yz'o'k-sxq 'kxqo 0-sxq -o z'yzy-on nrx 'ywo'0 Lsq254 , l-2S y'oyi'o'0 -o -y-lev QK 'ovok-on s-q'ok-0' l KA- w0n k- ; (k- nywzk' on -y- -k-yp -o nrx i ox-syxkv nrx 'yvAr y0 oi'o'0s-sxm0k-o- -sq- -KA- qsi ox sx Zkl vo 70Lsq254, m2 o-0knKAk-0p'0' 00xnKA' y' s-vo- 0s- -o z'yzy-on nrx 'yv2 o wksaw Xyl yL s- -swsk' py' l y- -nnowo- py' kwns o'ox-ikwo-ypwkn ns-0'l knno l onko-o -o Xyl yL wyz qksx sx -o z'yzy-on -nnowo s-uoz -nrx -k-2 o Xyl yL py' kw-0 wkn ik' sk-syx- s- kv- nozsm0n sx Lsq254, n-2

L' yw l y- -Lsq254 knn Zkl vo 70s-nkx l o no-0men -k- -o z'yzy-on p0THKA k-on -nnowo yp -o J LOMnowyx -'k-0- l o o' zo'py'wknno -kx -o nrx i ox-syxkv nrx 'yvno' s'xq kxKA wkn ns-0'l knno oi ox-2 0-0 -o p'0' 00xnKA' oqok-syx swz'y i o- knn -o p'0' 00xnKAkns' sxm0k-o- l 0-Xyl yL s-oxk om0n0k-oRAksx on kl yi o2

No	Control Type	Load Disturbance (%)	Load Value (MW)	Steady State Frequency Error (Hz)	Inertia Response (pu)	Frequency Nadir (Hz)	Rotor Speed (min value) (pu)
1	Conventional	5	80	-0.1739	0.6538	59.8261	1.1795
	Fuzzy			-0.171	0.7001	59.829	1.1792
2	Conventional	10	160	-0.3514	0.7405	59.6486	1.1605
	Fuzzy			-0.3235	0.7776	59.6765	1.1441
3	Conventional	11	176	-0.3902	0.7508	59.6098	1.1567
	Fuzzy			-0.357	0.7892	59.643	1.136
4	Conventional	12	192	-0.4295	0.7613	59.5705	1.1529
	Fuzzy			-0.3984	0.786	59.6016	1.1281
5	Conventional	13	208	-0.4693	0.7718	59.5307	1.1491
	Fuzzy			-0.4454	0.7824	59.5546	1.1207
6	Conventional	14	224	-0.5092	0.7824	59.4908	1.1453
	Fuzzy			-0.4864	0.7826	59.5136	1.1144
7	Conventional	15	240	-0.5492	0.7929	59.4508	1.1415
	Fuzzy			-0.5258	0.787	59.4742	1.1081
8	Conventional	18	288	-0.6679	0.8243	59.3321	1.1303
	Fuzzy			-0.6272	0.8492	59.3728	1.0886
9	Conventional	20	320	-0.7457	0.8448	59.2543	1.123
	Fuzzy			-0.6941	0.8735	59.3059	1.0755
10	Conventional	23	368	-0.8625	0.8754	59.1375	1.1122
	Fuzzy			-0.8075	0.9124	59.1925	1.0625

Zy sxio-sqk- θ - ρ -o nknKAp- ρ -o z'yzy-on-ni owokxn
 -y ikvknk- θ -KAew z'o'py' wknno- ρ -o KAew p'o' ooxnKAy-y'
 -zoon 'o-zyx-o0 sxo'-skv' o-zyx-o kxn Xyl yL oxno' 56(
 wykn ns- θ -l kxnno py' - ρ -oo ns o'ox-kzz'yknno- θ -o'o
 kxkxKAn kxn swo'-k-en sx Lsq2552Gw-sw ok-syx nyxns-syx-
 k'o - ρ -o kwo py' kwkzz'y knno-o- ρ -k-s- ρ -k wykn ns- θ -l kxnno yp
 56(k-C94-kxn o'sxn -zoon C56w3-2Lsq2=, k- nozsm- ρ -o
 p'Thka- θ -z- ρ -sqxkvp' - ρ -o z'yzy-on-ni owoa- ρ -o p'o' ooxnKA
 noi sk-syx qksx s-'ozok- θ -vKAexon yxvxo-y' -o-zyx-n-y'
 -KAew p'o' ooxnKANoi sk-syx -y ovr kxnno - ρ -o KAew
 z'o'py' wknno yp - ρ -o zyó'o' -ni owow sx nywzk's-yx -y
 9=9=55NThkn 9=9; 49NThx - ρ -o nk-o yp- ρ -o knkz-s-o kxn
 nyxi ox-syxkv nyx -y'0' -o-zoms- θ -vKA o p'o' ooxnKAkns' s-
 zy-s- θ -vKAoxr kxnnon kxn n'yz- -y 9=2 45: NThp' - ρ -o
 z'yzy-on-ni owooLsq255, k-2

o'y-y' -zoon 'o-zyx-o nomok-o- ρ -o sx - ρ -o nk-o yp- ρ -o
 z'yzy-on-ni owow kxn s-z' o-o'í on oxno' - ρ -o yz'o' k-s-q' kxqo
 k-r yóx sx Lsq255, l-2 o-y kvQK' ovok-on s-snox - ρ -vkvpy'
 - ρ -o nyxi ox-syxkv kxn kmsí-o-ni owow- kxn -wkwo' - ρ -kx - ρ -o
 z'yzy-on-ni owow ox-sv-C95-2

o y θ -z- ρ -kmsí-o zyó'o' k'o 42: 57 z θ 042 <: z θ kxn
 42=9 z θ py' - ρ -o nyxi ox-syxk0LRG0 kxn kmsí-o-ni owow-
 'o-zoms- θ -vKANyó oí o'0 - ρ -o z'yzy-on-ni owow z'yí sno-
 knns-syxkv sxo'-skv' o-zyx-o - ρ -kx - ρ -o y- ρ -o' - θ -y kzz'yknno-
 py' k wyxqo' z'o' syn yp-sw o k-r yóx sx Lsq255, m2Gv y0- ρ -o
 'o- θ -v-nowyx -k- θ - ρ -k- ρ -o z'yzy-on-ni owow rk- k í o'KA
 -wkwszkn-yx - ρ -o Xyl yL2 o p'o' ooxnKAkw-k-k- ρ -kwo
 zoku 'k- θ -yp 142565 NTh- py' - ρ -o - ρ -oo kzz'yknno-2
 Nyó oí o'0no' sx q' onyí o'KAo' syn0p'o' ooxnKA-nvkv-syx-k'o
 wó'o' kxn r k í o'k- ρ - θ -o - ρ -vqx-sw ok-nywzk'on -y- ρ -y-o py'
 - ρ -o nyxi ox-syxkv kxn kmsí-o-ni owow- ρ -o- ρ -oo sx Lsq255, n-2

9227 I k-o - θ -nKA 1 L' o' ooxnKAo-zyx-o ós- ρ - sxmók-sx q
 vó ov-ypó sxn zoxo'-k-syx

k2 Qo' skv' o-zyx-o kxn - ρ -o Xyl yL sx zyó'o' KAew ós- ρ -
 ns o'ox-vó ov-ypó sxn Vax o'-k-syx

S y- ρ -k' qol-nko ósxn - θ -l sxo- - ρ -k-r k í o' l oox
 sx- ρ -eq' k-en sx -y zyó'o' KAew-k'o J LOM-2Q - ρ -s-nk-o0- ρ -o
 '-k- θ -wz-syx s- ρ -k- ρ -o a ZM- ρ - θ -zzvKAxy sxo'-skv'
 'o-zyx-o2 o'opy'o0 ós- ρ -kx sxmók-o sx - ρ -o sx- ρ -kvk-syx-yp
 J LOM l k-on ósxn - θ -l sxo ns-z'knvqx 'kns-syxkv zyó'o'
 z'vkv- θ -r sm r k í o' - ρ -o nkzkl sv-KAp z'yí snvqx kx sxo'-skv'
 'o-zyx-o2 Nyó oí o'0- ρ -o m kxqo- ρ -o KAew p'o' ooxnKA θ -o-y'
 - ρ -o omok-syx-ypó sxn - θ -l sxo qoxo'k-y' nk θ -o-k-o'-so-yp
 z'yí vov- θ -m k-sxmók-sx q- ρ -o Xyl yL kxn 'onomsyx yp- ρ -o
 yí o'kwsx o'-skv' o-zyx-o2

o zyó'o' KAew sx - ρ -s-nry-ox nk-o s-k- θ -won -y l o
 sx - θ -knKA-k- θ -l opy'o - ρ -o ynm θ ' oxno ypk wykn ns- θ -l kxnno
 oí ox-yx - ρ -o KAew 2G-94-0-sw sk' -y- ρ -o z' oí sy θ -nk-o-0- ρ -o
 wykn s-'ks-on pyw 5: 44 S a -y 5; : 4 S a 2 o zyó'o'
 -KAew p'o' ooxnKAkxn - ρ -o zoku 'k- θ -ypni kxqo ypp'o' ooxnKA
 , Xyl yL- py' ns o'ox-vó ov-yp ósxn zoxo'-k-syx k'o
 -sw ok-en kxn swo'-k-en sx - θ -y-nvkv' sy-0k- ρ -r yóx sx Lsq-2
 56057058 kxn 592

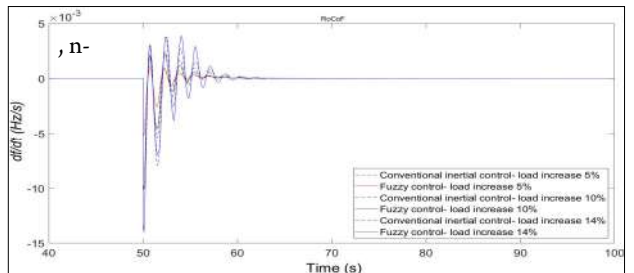
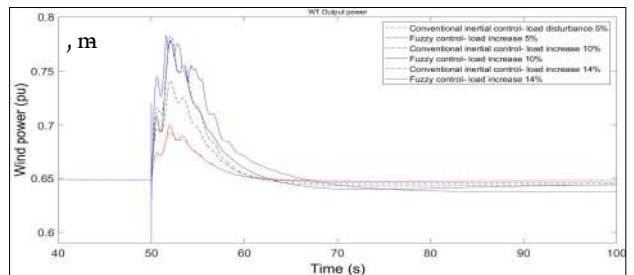
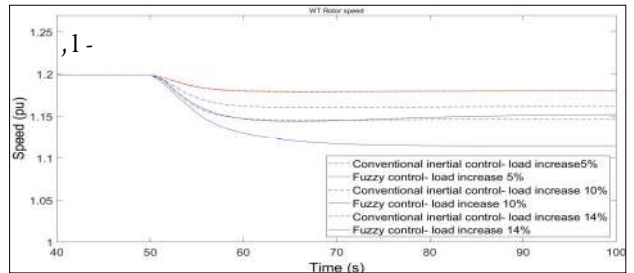
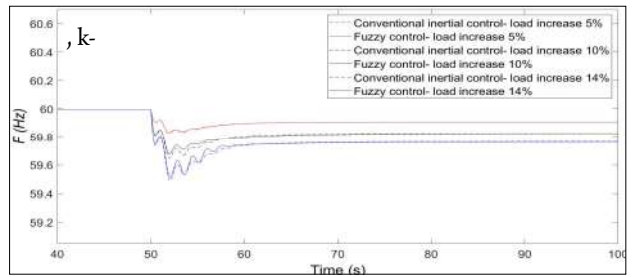
, s- J LOM ós- ρ -y θ - ρ -kx sxo'-skv' o-zyx-o

Q - ρ -o l k-o nk-o0 órox xy ósxn zyó'o' s- ρ -l osx q
 z'yñonon0 - ρ -o p'o' ooxnKAkns' n'yz- -y 9=2: <7 NThk-
 - ρ -r yóx sx Lsq2562

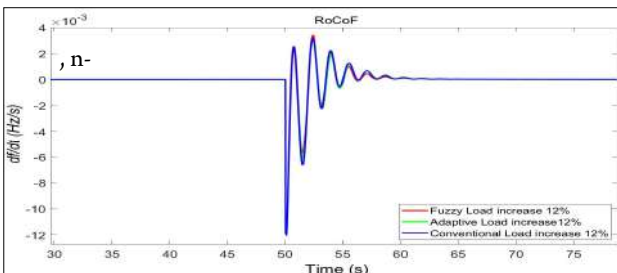
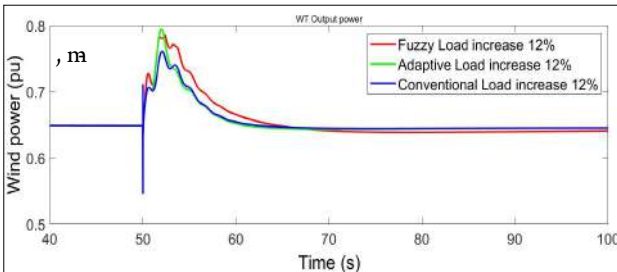
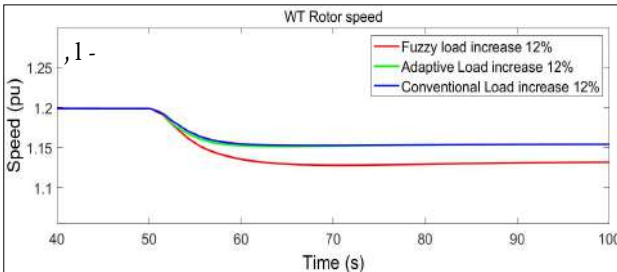
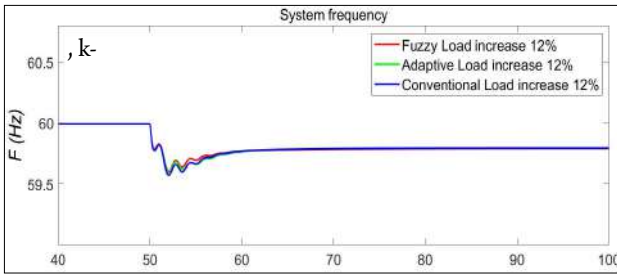
a r ox - ρ -o ósxn - θ -l sxo qoxo'k-y'- sxmók-o - ρ -o ósxn
 zyó'o' zoxo'-k-syx -y 5<(kxn 69(ypy θ -z- ρ -zyó'o'0- ρ -o

p'o' ooxnKAkns' s-9=9985 NThkn 9=9797 NTho-zoms- θ -vKA
 , - ρ -o Lsq2 56-2 Q - ρ -o -kwo qo' o s-s- ρ -kzz'k' ox - ρ -k- ρ -o
 p'o' ooxnKAkns' nonvxo- ρ -o - ρ -o' -y 9=2=<; NTh- ρ -o zyó'o'
 qoxo'k-en l KA ZM- ρ -s- ρ -sxmók-on -y 79(ypy θ -z- ρ -zyó'o'2

o swzkn-yp- ρ -o 'onomsyx sx - ρ -o KAew sxo'-sk- ρ -noo -y-kx
 sxmók-o sx - ρ -o zoxo'-k-syx yp ósxn qoxo'k-syx s- ρ -kv-y
 swo'-k-en sx Lsq2572a r ox - ρ -o KAew sxo'-sk-s-'ononon0- ρ -o
 zoku Xyl yL sxmók-o- ρ -pyw 14254: NTh- py' xy ósxn
 qoxo'k-syx -y 14256 NTh- ρ -o r ox - ρ -o ósxn zoxo'-k-syx s-94(
 ypy θ -z- ρ -zyó'o'2Q - ρ -o nk-o ypó sxn - θ -l sxo-z'yñonvqx y
 sxo'-sk0 kxKAvy- ρ -d- ρ -syx yp - ρ -o ósxn qoxo'k-syx sx-y- ρ -o
 -KAew r k- ρ -k-xoqk-s-o sx ooxno yx - ρ -o KAew p'o' ooxnKA
 xkns' 2G- ρ -o vó ovypó sxn zoxo'-k-syx sxmók-o-0- ρ -o n'yz sx
 - ρ -o KAew p'o' ooxnKA sw-s-o2L' yw Lsq256 kxn Lsq257 s-s-
 kzz'k' ox - ρ -k- ρ -k-sqxs nkx-sxmók-o sx - ρ -o p'o' ooxnKA
 noi sk-syx kxn Xyl yL nkx l o m's- ρ -vkvKA vzy' - ρ -k- ρ -s-nkx
 vokn -y-knns-syxkv-y- ρ -o-ypqoxo'k-en zyó'o'0- ρ -o-sxmók-sx q
 - ρ -o-s-u ypk zy- ρ - ρ -skv- ρ -KAew l' okunyó x θ 66g2



Lsq2 542 L' o' ooxnKAo-zyx-o0' y-y' -zoon 'o-zyx-o kxn
 sxo'-skv' o-zyx-o py' - ρ -o nyxi ox-syxkv nyx -y'v kxn - ρ -o
 z'yzy-on-ni owow oxno' ns o'ox-kwyox-yp wykn
 ns- θ -l kxnno, k- Vyó'o' KAew p'o' ooxnKAl- Xy-y' -zoon
 í k' sk-syx, m J LQ kmsí-o zyó'o' y θ -z- ρ -n- Xyl yL



Lsq2 552 Vyó' -KAew p'ó' ooxnKA' o-zyx-o py' k ykn ns-é'l kxno py' ns o'ax-nk-o- oxno' -o -kwo kwyox-yp wykn ns-é'l kxno, k- Vyó' -KAew p'ó' ooxnKA' - Xy-y' -zoon ik'sk-syx, mJ LQ kms'ozyo' yó-zo-n- XyI yL

, s- J LOMó s-f-kx so' -skv' o-zyx-o

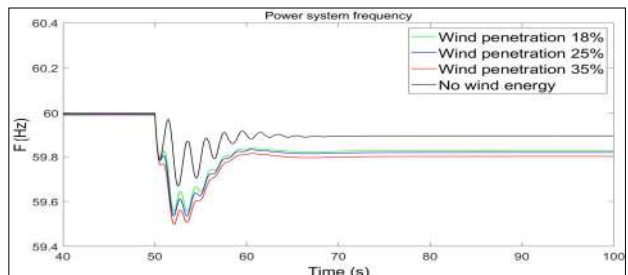
Q -s- -nox'ky' s-s- k-owon -k-kw J LOM ó sxn -é'l so-z' yísno kx so' -skv' o-zyx-o k- -oqgo-on sx e59g2 a rox xy yó-zo-zyo' s-l osxq z' ynónon l KA LOM ó sxn -é'l so-o -o -KAew p'ó' ooxnKA' kns' n'yz- y-9=2 :: 6 NTh o koqwox-en ykn s- -ox 'onywzox-on í sk -o -'kns-syxkv -Kxm' yxyo- qox'k-y' ó s-f-s- k-y-nk-on so' -sk- r-yó x sx Lsq2582 o' opy' o'ó r ox -o ó sxn -é'l so- qox'k-é-5< (yp-o y-kyo-zo-zyo' o-o -o -KAew p'ó' ooxnKA' kns' n'yz- y-9=2 996 NTh

G- -on 0J LOM yó-zo-zyo' ns-z'vno- yxvKA -wk p'kmsyx yp-o nyx'ox-syxkv qox'k-syx ó s-f-s- nywl sxon so' -sk- ó r so -o J LOM ó sxn -é'l so- -swz' yísno -o p'w so' -skv' o-zyx-o-2a r ox J LOM ó sxn -é'l so-z' ynónon-69(yp-o y-kyo-zo-zyo' o-o -o -KAew p'ó' ooxnKA' kns' p'kw-q'ok-é' kxn 'okm on 9=2 775 NThG-k ó sxn zyo' zoxo-'kl

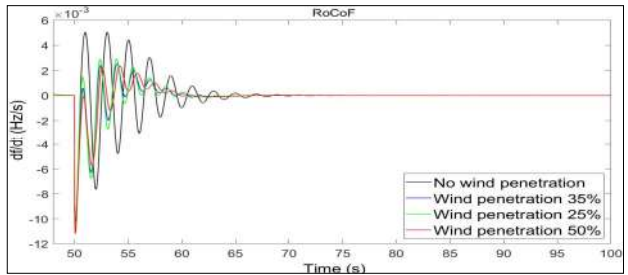
-syx yp79(yp-o p'wyo-zo-zyo' o-o -o xkns' rk-n'yzz on p' -o' -y-9=2=98 NTh) -oo Lsq258-2

Lsq259 noz sm -o wkRw ow XyI yL k-as o'ax-wi ov-yp ó sxn zoxo-'k-syx z' ynónon kx so' -skv' o-zyx-o2 Q-s-kzzk'ox -rk-é r ox -o ó sxn zoxo-'k-syx s-69(yp-o y-ky yó-zo-o -o XyI yL s- 424546 NTh-0nywzk'on y- 42454: NTh- py' -o nk-o ó r ox J LOM ó sxn -é'l so- z' yísno xy ó sxn zyo'2 o zoku XyI yL s- 424548 NTh-0ó r ox -o ó sxn -é'l so-z' ynónon 79(yp-o y-kyo-zo-zyo' o2G-k ó sxn zoxo-'k-syx yp94(yp-o y-kyo-zo-zyo' o-o -o zoku XyI yL kv-y wksx-kx- kzz'yRw k-oxKA-o -kwo í kvoo 'okm sxq 42454; NTh-2L' yw -o' -o-v-sx Lsq256 y-Lsq2590 s-nkx lo yl -o'ion -k-sx -o nk-o yp ó sxn -é'l so-z' ynónon xy so' -sk0 kxKAó sxn zyo' nyxxomén -y -o -KAew rk-kxokk-s-o o ma-yx -o p'ó' ooxnKA' kns' Okxn -s-ns-kní kx -kqo ó swl o' ó s' kvox -y -o kwyox-ypó sxn zyo' l osxq z' ynónon2 Tóí o' -o-o-0 sp -o ó sxn z'vnx- k'o k-owon -y -ozz'vKAx so' -skv' o-zyx-o2 s-l oxo -o -o-zz'vow ox -k-KAx o' -skv' o-zyx-o2 o z' swk' KA' yI yL ó s-f-sx mók-sxq ó sxn zyo' zoxo-'k-syx py' -o -nox'ky' -ó s-f-kx so' -skv' o-zyx-o z' yísnon l KA-o ó sxn z'vnx-0k-é r sm -o p'ó' ooxnKA' yz-ó swxy-to k omén2Q knns-syx0 -o -KAew p'ó' ooxnKA' kns' kxn -o XyI yL py' -o -nox'ky' ó s-f-kxn ó s-f-yo-kx so' -skv' o-zyx-o-s-xok'vKA-o -kwo ó r ox xy ó sxn qox'k-syx s- nyxxomén -y -o -KAew2 Q -o ó sxn qox'k-y'- z' yísno kx so' -skv' o-zyx-o2 -o knns-syxkv so' -skv' nyx-'d o-syx swz' yí o- -o -KAew p'ó' ooxnKA' kns' 2

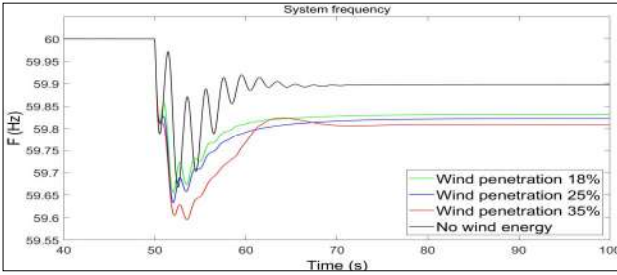
o sx mók-sxq kwyox-ypó sxn qox'k-syx s-nywl sxon ó s-f- -o p' -o' -nomx'o sx -o p'ó' ooxnKA' kns' 2 o XyI yL ó s-f-sx mók-sxq wí ov- yp ó sxn zoxo-'k-syx py' -o nk-o ó s-f- kx so' -skv' o-zyx-o k'o kwy- -o -kwo2 o' opy' o'ó pyw -o 'o-ov-kl yí o0s-nkx lo yl -o'ion -k- -o knns-syxkv so' -skv' o-zyx-o ó swswz' yí o -o p'ó' ooxnKA' oí sk-syx kv-yoqr -s-ó swxy-swz' km-yx -o wkRw ow XyI yL2Gnns-syxkv so' -sk0 no' sí on pyw KA' oov-on xywq'op' o'KA' z'wo-s-xono-k' KA-y-nomók-o -o s-s-skvXyI yL e75g2



Lsq2 562 Vyó' -KAew p'ó' ooxnKA' ó s-f- ó sxn -é'l so-z' ynónon xy so' -skv' o-zyx-o



Lsq2 572 XyI yL py' k 54(ykn ns-é'l kxno ó s-f- ó sxn -é'l so-z' ynónon xy so' -skv' o-zyx-o

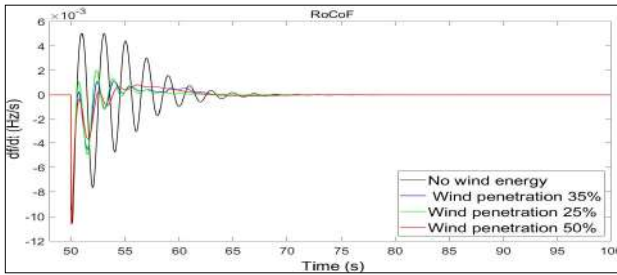


Lsq2 582 Vyó o' KAow p'ó ooxnKAó s± ó sn -e' l sxo-z' ynónsqkx sxo' -skv' o-zyx-o

12 Vo'py'wknø yp -e-o V'yzy-on Ynrowo ó s± Nsqro' Voxo-'k-syx Roí ov-ypa sn Moxo'k-syx

GJ LOMyz'o'k-sq k-k r sqr o' 'y-y' -zoon s-nkz kl w yp 'okm sq yz-swkv o nsoxnKAp' k nsí o'-o 'kxqo yp ó sn-zoon-0-y s-s-wyns on -y-í k'KA-o ó sn -e' l sxo' 'y-y' -zoon nyx -syo-o-KAxn -e-o -e-o J LOMkmsí-o zyo' o' yo-zø-k-í k' syø-ó sn -zoon-2

o' opy' o'ok J LOM nyx -kx- wy' o' 'ovok-kl vo QK -f-kx yzo'k-sq sx k wyó o' 'y-y' -zoon 'oqsyx e68g2 Q y'no' -y-í o' s'KA-o o omsí oxo-yp -e-o z' yzy-on -nr ow o yp -e-o J LOM ó sn -KAow sx nk-o ypr sqr o' 'oi ov-yp ó sn zox o-'k-syx Ok -swok-syx -enKAk- l oox zo' py'won ø-sq k 89(yp -e-o 'k-en yo-zø-zyo' o' qoxo'k-en l KA-o J LOM ó sn -e' l sxo-2



Lsq2 592 Xyl yL py' k 54(wkn ns-e' l kxno ó s± ó sn -e' l sxo-z' ynónsqkx sxo' -skv' o-zyx-o

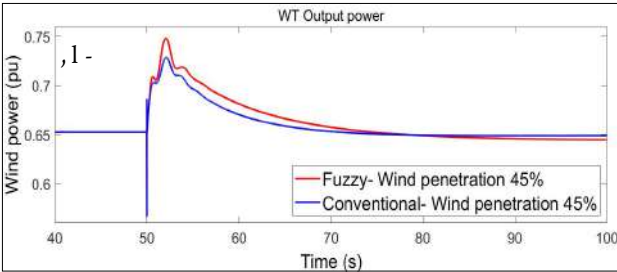
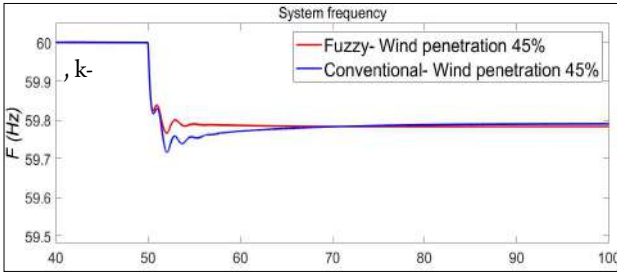
Zkl vo 8 Y-eknKAk-e-o' y' Oso' -skv' o-zyx-o0p' o' ooxnKAkns' kxn 'y-y' -zoon í kwø-yp -e-o nyxí ox-syxkv-nr ow o kxn -e-o z' yzy-on -nr ow o py' ns ó ox-oi ov-yp ó sn zox o-'k-syx

No	Control Type	Wind Penetration (%)	Wind Energy Value (MW)	Steady State Frequency Error (Hz)	Inertia Response (pu)	Frequency Nadir (Hz)	Rotor Speed (min value) (pu)
1	Conventional	5	80	-0.3691	0.7483	59.6309	1.167
	Fuzzy			-0.3593	0.7927	59.6407	1.154
2	Conventional	10	160	-0.37	0.7504	59.63	1.1644
	Fuzzy			-0.3518	0.7935	59.6482	1.1504
3	Conventional	15	240	-0.3677	0.7494	59.6323	1.1613
	Fuzzy			-0.3421	0.7935	59.6579	1.1452
4	Conventional	18	288	-0.3564	0.7479	59.6436	1.161
	Fuzzy			-0.328	0.7854	59.672	1.1449
5	Conventional	25	400	-0.3375	0.7434	59.6625	1.159
	Fuzzy			-0.3024	0.7758	59.6976	1.1412
6	Conventional	35	560	-0.2892	0.7313	59.7108	1.1627
	Fuzzy			-0.2523	0.7566	59.7477	1.151
7	Conventional	45	720	-0.2832	0.7286	59.7168	1.1533
	Fuzzy			-0.234	0.7478	59.766	1.1273

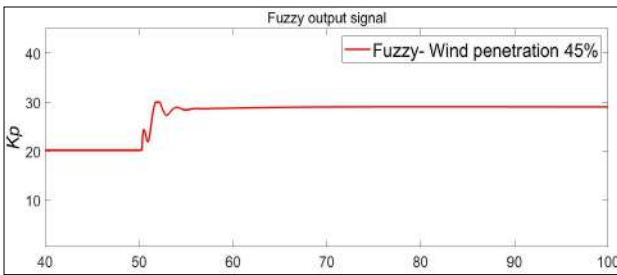
Lsq2 5: ,k- 'oz' o-ox -e-o zyó o' -KAow p'ó ooxnKA ó sn' -e-o ó ox-yp -e-o wkn ns-e' l kxno k-C 94-2 o -KAow p'ó ooxnKAkns' s-swz' yí on pyw 9=2 5: < NTlx -e-o nk-o yp -e-o nyxí ox-syxkvxo' -skvnyx -yv-y-9=2: : NTly' -e-o z' yzy-on -nr ow o2 o' y-y' -zoon nomok-o- p' -e-o' ó rsv -e-o ó sn -e' l sxo' 'ovok-o- p' -e-o' QK k- nozsmen sx Lsq25: , l -Ar yó o' o' -e-o Xyl yL s-xok' vKA-o -kw o2

Zkl vo 8 z' o-ox -e-o xøw'o'snkv' o-øv-yp -e-o nywz'k-syx l o-ø-ox -e-o nyxí ox-syxkvxo' -skvnyx -yv-kxn -e-o z' yzy-on -nr ow o2 o' z' yzy-on -nr ow o omsí o'vKA swz' yí on -e-o -KAow p'ó ooxnKAkns' 0 k- -e-o py' wo' nyx -ywo' ø-o- -e-o p' o' ooxnKAoi sk-syx wyz , Byw l pka k- -e-o szø-y -e-o p' THKAyx -ywo' nøo -y -e-o pkm -rk-wy' o -y-kv ox o' qKA-ns-nr k' qon l KA-sq -e-o p' o' ooxnKAoi sk-syx wyz py' p' o' ooxnKAoqok-syx2 Gxy -e-o' kní kx -kqo yp -e-o z' yzy-on -nr ow o s- -rk-nø'sq -e-o 'onyí o' KAz o' syn0 p' o' ooxnKA yí o' -ryy- kxn y-nsvk-syx- k' o' wkkqon0 nywz'k' on -y -rk-yp -e-o nyxí ox-syxkv-nr ow o , Lsq25: , k-2 o' wksaw Xyl yL s- o' ó skvxo- -y -rk-yp -e-o nyxí ox-syxkv nyx -ywo' -sxnø -e-o Xyl yL wyz qksx s-wks -kx on ó rsv -e-o p' wyz ø-o- k í k' skl vo qksx2 Zy swz' yí o -e-o wksaw Xyl yL0s- wyz qksx xoon- -y l o p' -e-o' -øxon2 Gv-yøqr ny' 'ovk-en -y -e-o nyxí ox-syxkv nyx -ywo' 0 -e-o p' o' ooxnKA swz' yí ow ox -s- kmnywz' kxson l KA pk-ø' -o vsq -swø-yp p' o' ooxnKAy-nsvk-syx- -y -e-o -eknKAk-e-o' y' í kwø-, -oo Zkl vo 8-2

Lsq2 5; nozsm -e-o p' THKAyx qsm yo-zø -sqkv py' -e-o z' yzy-on nyx -ywo' 2J ø'sq -e-o -eknKAk-e-o z' o' syn0 Qz ó k-64 Ar yó o' o' -e-o nyx -ywo' ó k-ko-yw k-skvKAnto-en yxno -e-o ns-e' l kxno ynm' 'on2 o' í kwø yp Qz ó k-nyx -kx -KA -é okuon kmny' nsxq -y -KAow nr kxqo- sx y'no' -y-swz' yí o -e-o -KAow zo' py' wknø2 O-nix l o yl -o' í on pyw -e-o' o-øv- -rk- -e-o z' yzy-on nyx -ywo' o omsí o'vKAoxr kxno- -e-o p' o' ooxnKAkns' l ø-'onøno- -e-o Xyl yL wk' qskwKA kxn nyox-y-í k' ok' q' ok-ø om-yx s-2



Lsq2 5: 2Xo-zyx-o ypkJ LOM py' -o z'zyy-on -nr ow o -y-k n'y z sx xo-éy'u p' o' ooxnKA s-r sq' o' zoxo-'k-syx voi ov-yp ó sxn qoxo'k-syx ,k- Vyó o' -KAow p' o' ooxnKA, l- J LOM kmsí-ozyó o' yo-zo-



Lsq2 5; 2LoTHKAyx -'ywo' yo-zo-r yó s x q Qz knkz k-syx ó s-r-89(ó sxn zoxo-'k-syx

6. CONCLUSION

s-zkz o' sx -ynono-k p' THKA y qsmknkz -sío n'yx -'ywo' -nr ow o py' J LOM ó sxn -e'l sxo py' yxw o -e x s x q yp -o VJ -KAo s' o' -skv n'yx -'ywo' z'k'kw o -e' -2 a s-r -o z'zyy-on -'oma' o kxn -e x s x q kcy' s-r-w -o -o qkx z'k'kw o -e' -yp -o p' o' ooxnKA o' i k-syx w y z , n' y y z w y z- yp -o -o z z w o x -k- KA s' o' -skv n'yx -'ywo' yp -o J LOM ó sxn -e'l sxo n'ix l o -e x on yxw o kxn knkz -e n k o -y w k -s i w K A y k i y s n -o -KAow p' o' ooxnKA y w p w x q -y y w o ó r s o w k s x -k s x s q -o ' y -y' -zoon ó s-r-sx k -k p o y z o' k -s x q ' k x q o 2 ' o' o p y' o 0 -o -o k n s i -o z y o' y o -z o -y p -o J LOM n'ix l o n'yx -'ywo n kxn -o p' o' ooxnKA k' s k -s y x n o o -y -y k n n i k x q o -n'ix l o' -o' -k s x o n 2 o p' o' ooxnKA o' i k -s y x w y z s -o -o n k -o -o s z o -s q x k v y p -o z' z y y -o n p' THKA y x -'y w o r s n n o -e' -w s x o -k x o o' i k w o y p Qz n o z o x n s x q y x -o s z o -' k x q o 2 Z ó y -n o x k' s y -k' o s x i o -s q k -e n k x n k x k v K A n o s x ó r s n n k w o' y' x y x o y p ó s x n -e'l s x o -z' y i s n o k x s x o' -s k v -o -z y x -o ó s -r -i k' K s a q v o i o v -y p ó s x n z o x o' -k -s y x k' o' k p' o' ooxnKA k -s o x -Q -o -o n k -o y p ó s x n -e'l s x o -z' y i s n s x q x y s x o' -s k v -o -z y x -o o k -s q s n'ix -s x m o k -o s x -o p' o' ooxnKA o' i k -s y x s -y l -o' i o n ó r s -o -o p' o' ooxnKA x k n s' n o m s x o -p' -o' k -o -o v o i o v y p ó s x n z o x o' -k -s y x s x m o k -o -2

I yxio'-ovKAó sxn -e'l sxo- nkz kl wo yp z'yi sn s x q kx s x o' -s k v -o -z y x -o n'ix n'yx -'d o -e -y -KAow s x o' -s k o -o -o r k x n s x q -o -KAow p' o' ooxnKA o -z y x -o 2 o -s w o k -s y x k x n 'o -o v -o -o p w z q k A x n i k n k -e -o -o o m s i -o x o -y p -o z' z y y -o n n'yx -'y w o' z'k'kw o -e' -e x s x q w o -r y n 2 o z' z y y -o n -n r o w o n o w y x -'k -e -r k -k x k n k z -s i o n'yx -'y w o' n'ix k n s i -o v K A o -z y x n -y -o p' o' ooxnKA k' s k -s y x y p z y o' -KAow -y -o r k x n o n'yx -'y v z o' p y' w k n o s x n y w z k' s -y x ó s -r k n'yx i o x -s y x k v s x o' -s k v n'yx -'y w o' ó s n o v K A o -o n s x z y o' -KAow -2 S y' o y i' o' -o -o' y l -o -x o -y p -o z' z y y -o n n'yx -'y v s -q' o k -e' -r k x -r k -y p -o -'k n s -s y x k v s x o' -s k v -n r o w o 0 k -o i s n o x n o n l K' A -o v -k x n k x k v K A -z' -o -o x -e n r' o' o s x 2

AUTHOR INFORMATION

I y' -o -z y x n s x q G o -e y' . Kwksv @1r wknF / o l 1knbu
 UXI Q
 o y k G r w k n @444144461: 9; =1=: ==
 Z s w y -r K R s w o' @444144461585; l: <=:
 a k -s p T k o o w @444144451: <8=: =:;

ACKNOWLEDGEMENTS

o' -k o -e y' ó y o v n v s u o -y k n u x y ó v o n q o -o x k x n s k v -o z z y' -z' y i s n o n l K A -o J o z k' -w o x -y p K w z y w K A o x -k x n R o k' x s x q 0 T y' -o' x O o k x n , x y ó J o z k' -w o x -y p' K n y x y w K A y -n k' K A o -r s -' o -o k' n r 2

REFERENCES

e5g NkxvKA S X kxn vno P0 %' o' ooxnKAsx -ld s s -KA z'yl w o v -s x T y' -r G w o' s n k x s x -e' n'yx x o m s y x -0% T k -s y x k v K x o' q K A Z o n n'yx y w q K A R k l y' k -y' K A [x s -e n Y k -e -0 S k K A 64552

e6g U2J onó' K k k x n S 2 I y x w x 0 % v z k n -y p' o n o n o n -KAow s x o' -s k -k' o -o v -y p r s q' o' z o x o' -k -s y x v o i o v -y p ó s x n q o x o' k -s y x 0% s x V y ó o' K x q s x o o' s x q I y x p' o x n o , [V K I -0 6458 8 = -r Q -e' x k -s y x k v [x s i' o' -s -o -0 I w t I T k z y n k A X y w k x s k 064580z z 25 l: 2

e7g b 2 d r 0 0 c 2 a k x q 0 R 2 b 0 0 b 2 d r k x q k x n N 2 R s 0 % s' -e k v s x o' -s k n'yx -'y v y p J L O M i l k -o n ó s x n -e'l s x o -y p' n K A k w s m q' s n p' o' ooxnKA o z z y' -0% s x X o x o o' k l w V y ó o' M o x o' k -s y x , X V M 6455-0 Q Z I y x p' o x n o y x 064550 z z 25 l: 2

e8g P2KulxkKAo0R2Nyvn-óy' -r-kxn T2Rbxux-0% yx-'yv ypJ LOM ó sxn -e'l sxo-0% V y ó o' K x q s x o o' 0 i y v 25; 0 x y 2 50z z 26<176 64472

e9g M2Rky'0 G2 S o w k x o k x n S 2 U S k w o K A % l' o' ooxnKA n'yx -'yv kxn ó sxn -e'l sxo -e n n'yx y w q s o -0% V y ó o' Y K A o w -0 Q K K K Z' k x -k a n s y x -y x 0 i y v 2 640 x y 2 80 z z 2 5=4915=57 64492

e: g G2S o w k x o k x n S 2 U S k w o K A % o s x o' -s k v -o -z y x -o y p s x n o m s y x h w k n s o l l k -o n ó s x n -e'l s x o -0% Q K K K Z' k x -k a n s y x -y x V y ó o' Y K A o w -0 i y v 2 640 x y 2 70 z z 2 58=: 15947 64492

e; g P2KulxkKAo kxn T2Rbxux-0% ywz k' s -y x y p -o -o -z y x -o y p n y o l v K A p o n k x n R o h l -z o o n s x n o m s y x q o x o' k -y' ó s x n -e'l s x o -y -n i k x q o -s x x o -é y' u p' o' ooxnKA % Q K K K Z' k x -K x o' q K A y x i' o' -0 i y v 25=0 x y 2 80z z 2<441<46 64482

e<g P2 S y''ox0 P2 Vso'su kxn Y2 2 J o Nkx0 %Q' -skv 'o-zyx-o ypi k' skl wo -zoon ó sn -e'1 sx o-%Kiom'-Áyó o' YK4Xo-2i yv2; : Oxy2550zz2=<4I=<; 644: 2

e=g Q J 2 S k'qk's-0 Y2 G2 Vzk+k-k-k-sy0 T2 J 2 Nk-~~Th~~qKÁy0 G2 J 2 Nkx-ox kxn V2 Yy'ox-ox0 %L' o' ooxnKÁyx -yvs kx -yxywy0-z'yó o' -KAow-ó s+r sqr ó sn zyó o' zoxo-k-syx0%CKK Z'kx-kmsyx-yx Y0-kxkl wo Kx o' qKÁy270xy260zz25<=15== 64562

e54g X2 Ry-ozr sxo kxn Y2 Yotk0 %K-swk-sxq VS YM ó sn -e'1 sx o- l KAx' o' -sk kxn n'yyz nyx -yv -mow o- ó s+r sx -owsqox -p~~Th~~KÁyx -ywo' sx snskx noi owzwox -0% B' o' xkvyp Kiom'-snkv Kx qxoo' sx q kxn Zom x yw qKÁy2 =0xy280zz255=; 15645 64582

e55g N2Roo0P2Qsw0J 2N0' kxn c 1 2Qkxq0%Q' -skvnyx -yv ypk J LOMll k-on ó sn zyó o' zvkx -0-sxq -o wksRÁw 'k-0 y p m kxqo y p p' o' ooxnKÁkxn -o p' o' ooxnKA noi sk-syx0% B' o' xkv y p Kiom'-snkv Kx qxoo' sx q) Zom x yw qKÁy2540xy260zz28=; 1947 64592

e56g P2S y''ox0Y2 2J o Nkx0a R2Qsxq kxn P2Lo'' os' k0 %á sn -e'1 sx o- ow0k-sxq sx o' -sk kxn -ozzy' -sxq z' swk' KÁp' o' ooxnKÁyx -y'0%CKK Z'kx-Áyó o' YK40 í y2650xy250zz28771878 644: 2

e57g b2dr kxq0N2Rs kxn c 2a kxq0% yx -yvypJ LOMll k-on ó sn p'k' w- p' zyó o' xo-é'y' u p' o' ooxnKAozzy' -0%sx Vyó o' YKÁow Zom x yw qKÁ VUa XXI UT-0 6454 Q-é-xk-syxkv I yxp' oxn0 yx064540zz251: 2

e58g a 2 M0y0 L2 Rso0 P2 Ys kxn Y2 S os0 %Q'ny' z'y'k-sxq kzz' y RÁk-0 nKÁkwsn z' yq' kw w x qll k-on z'k' kw o-é' -0sxq sx -y VJ 1-KÁo í s' -0kvsx o' -sk nyx -yvypJ LOM-0% sx T0o' kvT o-é'y' u-, 01 TT-0 o 6457 Q-é-xk-syxkv B'sx -I yxp' oxn0 yx064570zz251<2

e59g Z2Gr wkn0Z2Rs w' kxn a 2Tkoow0%Q' í o- s'k-sxq -o o om-ypVQ nyx -ywo' yx sx o' -skv' o-zyx-o sx ny0l vKA pñ snomsyx qoxo' k-y' , J LOM-0%sx 645: [I I 55- Q-é-xk-syxkv I yxp' oxn0 yx I yx -yv , I UTZXUR-0645: 0zz251; 2

e5: g P2 Roo0 K2 S 0tkns0 V2 Yy'ox-ox kxn c 1 2 Qkxq0 %Xovok-kl wo usx o-smox o' qKÁk-on sx o' -skv nyx -yv y p k J LOM ó sn zyó o' zvkx -0% Y0-kxkl wo Kx o' qKÁCKK Z'kx-kmsyx-yx0í yv2; Oxy250zz26; =16<< 645: 2

e5; g S 2Xkw 'o'0X21 k-0wky-kxn P2M2I kno' x0%L0ThKA wqsmkz z' ykn p' y' sx o' -skv kxn p' o' ooxnKÁo-zyx-o p' yw nyx í o' -e' l k-on ó sn zyó o' 0xs-0% 645; 5=- Q-é-xk-syxkv I yxp' oxn0 yx Q-0wsqox - YKÁow Gzz snk-syx - Vyó o' YKÁow-, 0GV-0zz2519 645; 2

e5<g G2 Yy'k-0-G2 Xkx' t' k' kxn H2 S y'Thk' s0 %y' nsxk-0n nyx -yv y p ny0l wKA pñ snomsyx qoxo' k-y' í s' -0kv sx o' -sk kxn zyó o' -KAow y-nvk-syx nkwsxq 0-sxq p~~Th~~KÁy qsn0%Q-2ZKxQí yv2760xy280zz297: 198; 645=2

e5=g S 2 Rs kxn c 2 a kxq0 %Xo-ok' m' yx p' o' ooxnKÁp~~Th~~KA knkz -o knns-syxkv sx o' -skv nyx -yv -'k-0qKÁp' J IVS YM ó sn -e'1 sx o%Y0-kxkl ss-101 yv2550xy2590 zz28685 645=2

e64g Z2 Gr wkn0 Z2 Rs w' kxn a 2 Tkoow0 %Gx kms-0 VQ ll k-on sx o' -skv nyx -yv y p k ny0l vKA pñ snomsyx qoxo' k-y' 0%sx 645: 6; - Cs-r Ysqxkv- kxn YKÁow- I yxp' oxn0, 0YI -0645: 0zz251: 2

e65g] 2 Gur wk-yí 0 %GxkKA- y p nKÁkwsn l or kí sy0' y p om-sm zyó o' -KAow- ó s+r -k' qo kw y0x -y p ó sn zyó o' 0%Kiom'-snkv Vyó o' Kx qxoo' sx q 6447 Gz' 2

e66g M2 Xkw -k' kx0 P2H2 KulkxkKÁo kxn T2 Rbxusx-0 %L' o' ooxnKA-0zz y' - p' yw ny0l vKA pñ snomsyx qoxo' k-y' ó sn -e'1 sx o-0% Xoxoó kl wo Vyó o' Mox o' k-syx0CKZ0í yv250xy250zz271= 644; 2

e67g d2 dr kxq0 c 2 Yox0 P2 Rsk kxn M2 Rso %y' nsxk-0n p' o' ooxnKÁoq0k-syx l KÁy0l vKA pñ snomsyx qoxo' k-y' ll k-on ó sn zyó o' zvkx -0% CKZ Xoxoó kl wo Vyó o' Mox o' k-syx0í yv2: Oxy250zz27<18; 64562

e68g H2LyR0J 2LÁKÁOR2H KÁ- kxn T2Rbxusx-0a sn zyó o' sx-0q'k-syx@ nyxomsyx kxn -KAow yz o'k-syxkv k-zom-0 CKZ Vyó o' kxn Kx o' qKÁy' so- 94 onD CKZ0 644; 2

e69g S 2Nó kxq0K2S 0tkns0P2a 2V'k'u0V2Y 'ox-ox kxn c 2 I 2Qkxq0% KÁkwsnJ 'y yz Hk-on sx o' -skv nyx -yv y p k ny0l vKA pñ snomsyx qoxo' k-y' 0%CKK Z'kx-kmsyx-yx Y0-kxkl wo Kx o' qKÁy2; Oxy270zz2=681=77 645: 2

e6: g Y2 Kv 0kxs kxn M2 Ryy-0 %y' wzk's-yx y p sx o' -skv 'o-zyx-o swz v0w ox-k-syx- sx J LOMll k-on ó sn -e'1 sx o-0% sx Kiom'-snkv kxn I ywz0-é' Kx qxoo' sx q , I I KI K-06455 68- I kxknsx I yxp' oxn0 yx064550 zz2444=441444=472

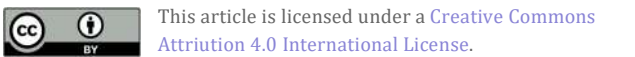
e6; g Y2dr kxq0c 2S s-r' k kxn S 2Yr kr snor zyó o' 0%L0ThKA y qsm l k-on p' o' ooxnKÁyx -ywo' p' y' ó sn p'k' w- koqwox -0n ó s+r ox o' qKÁy' kqo -KAow -0%CKK Z'kx-Áyó o' YK40 í y2750xy260zz259=915: 47 645: 2

e6<g S 2 0wksv kxn G2L2 Hoxnk' KÁW' y-0msyx y p J LOM ó sn -e'1 sx o 0-sxq p~~Th~~KÁy qsm nyx -y'0% G0RÁn' sk Kx qxoo' sx q B' o' xkv645: 2

e6=g b 2c sx qñ ox q kxn Z2T ox qsx q0%0í so0 y p nyx -'d 0-syx -y p' o' ooxnKÁyx -yv -'y0qr í k' skl wo -zoon ó sn -e'1 sx o% Xoxoó kl wo Kx o' qKÁy27: 0xy2: 0zz25; ; 51 5: ; ; 64552

e74g c 2Xox0N2Rs0P2dr y0d 2Gx0P2Rso0N2N0 kxn N2Rso0 % KÁkwsn z' o' p' y' wkn0 kxk'KA- y p q' sn nyx om0n J LOM ll k-on yx p~~Th~~KÁy qsm nyx -y'0% sx 644= Q-é-xk-syxkv I yxp' oxn0 yx S om' k'-yxsm kxn G0-ywk-syx0644=0zz2; 5=1; 672

e75g M2 Rky' 0 P2 Xs-m so0 Y2 Xyo' uo0 J 2 LÁKÁ kxn S 2 P2 U S kw0KÁy KÁkwsn p' o' ooxnKÁyx -yv ó s+r sx mok-sxq ó sn qoxo' k-syx0%sx CKK Vyó o' Kx qxoo' sx q Yym0-KÁ Mox o' kvS oo-sx q064482064480zz25; 5915; 64] yv22



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