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Fuzzy-Logic-Controlled Four Bus Micro-Grid System Employing-Hybrid-Power-Flow-Controller

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Abstract

Hybrid –Power*Flow*Controller (H.P.F.C)finds place between weak buses in multi-bus-systems to moderate the-effects of-voltage-sag. _This exertion deals–with-PQ-enhancement-of-4Bus*system (F.B.S) using H.P.F.C. Simulation is done for open loop and closed loop HPFC 4bus-system with HC (Hysteresis controller) and Fuzzy Logic controller –and-the-outcomes are compared-in-terms-of settling time &steady-state-error. The outcomes represent that the-superior-performance-of Closed-loop-HPFC-Four-bus system with-fuzzy-logic-controller. The-simulation-outcomes represent the ability of the H.P.F.C in MGS to improve the power-quality.Settling time is abridged from0.87 to 0.62sec and steady-state-error of voltage in FBS is abridged from0.9 to0.1 V using FLC.

Keywords: *Hybrid Power Flow Controller (HPFC), FACTS Controller, Unified Power Flow Controller (UPFC), Four Bus System (FBS), Hysteresis Controller (HC), SVC, Fuzzy Logic Controller (FLC), full and continuous controls, transient stability.*

INTRODUCTION

Because of the quick consumption of petroleum product and climate contamination individuals were presently pulled in towards non-regular fuel sources like PV, wind, hydro and so on Sun oriented and wind energy assets were bounteously accessible everywhere on the world. For the fluctuating idea of environmentally friendly power assets power age from environmentally friendly power frameworks were discontinuous. These conditions persuaded to consolidate at least two fuel sources with capacity framework to make Hybrid Renewable Energy System [1–3]. A disengaged half and half framework gave a higher productivity with an ease of energy creation, contrasted with the framework with a solitary source [4]. It was important to deal with changes in the produced power which was differing occasionally [5]. In writing [5-10] various sorts of HRES were presented which were working in framework associated or independent mode. HRES framework energy the board was finished by utilizing PI regulator in [6, 9]. It was finished by controlling a buck-support bidirectional converter for battery charging and releasing. A current control system for power balance by PI regulator was introduced in [8].

The customary regulator configuration relies upon numerical displaying of the framework. For complex framework the numerical model can't be appropriately characterized. Despite all the framework boundaries were known, there might be boundary varieties during the activity of the framework. So it was hard to plan regulator boundaries and additional time was required [10]. Numerous analysts were worked with most recent regulators, for example, prescient regulator [11], sliding mode regulator [12], H-endlessness regulator [13] for better consistent state and transient reaction of frameworks. These control methods rely upon complex numerical investigation. To keep away from the troubles in regulator planning, clever regulators were utilized [14]. For better outcomes astute regulator were presently applied in different crossover energy framework issues [15-17]. A use of FLC for inverter voltage and recurrence control was outlined in [10]. FLC functioned admirably even after varieties in framework boundary and working conditions [17]. Here a fluffy rationale based regulator for battery charging or releasing was proposed and executed for framework power stream control to smother the force vacillation and to supply a quality capacity to stack.

Control procedures for 3stage-4leg-voltage source inverters in self-sufficient miniature networks: an audit was introduced by Reza. The point was to give a review of the fundamental attributes of as of late utilized control methodologies for 4leg VSIs working in independent miniature matrices. Initial, 2regularly utilized four-wire inverter designs were talked about, and their points of interest and hindrances were analyzed. [18-19] Author presented ideal force stream count with moth-fire streamlining calculation. This work proposed an improved moth fire advancement (IMFO) calculation to viably explain the ideal power stream issues. The idea of moth fire enhancement was enlivened from the development of moth towards the moon course. IMFO was basically founded on the idea of MFO with changing the way of moths in new twisting around the fire.

Voltage limit control of measured staggered converter based brought together force stream regulator under lopsided framework conditions were proposed by Man. The secluded staggered converter-based brought together force stream regulator (MMC-UPFC) had the option to work under lopsided framework conditions with symmetric segment decoupling. Notwithstanding, the limitation of the voltage furthest reaches of UPFC was not thought of and no security plans are explored to shield the UPFC from over modulation under uneven lattice conditions. To tackle this issue, this work proposed the fell control plot for MMC-UPFC dependent on voltage limit control and symmetric part decoupling to adjust the air conditioner current of the transmission line. UPFC-based line over-burden control for power framework security improvement was introduced by Song.

Creator presented Liu Transformer-less UPFC utilizing the course staggered inverter. Next Nonlinear attractive equal circuit-based ongoing SEN transformer electromagnetic transient model on FPGA for HIL copying was introduced by Liu.

Exploration on an improved mixture bound together force stream regulator was recommended by Chen. At that point, this work presented the innovation of the IHUPFC in force stream guideline and transmission capacity improvement. Besides [24], the benefits of the IHUPFC in execution and structure were examined. The IST had more straightforward structure and bigger force stream control region than a "SEN" transformer, and the IHUPFC gives a constant dynamic and receptive force stream control.

Transformer-less-UPFC utilizing the course-MLI was recommended by Liu. HPFC-consistent state demonstrated control and functional application. Consistent state model of the HPFC for power stream and ideal force stream examines were introduced, considering the various control methods of the gadget. A technique for control mode exchanging and limit taking care of in force stream estimations was proposed. The OPF model of the HPFC spoke to all the gadget control and actual cutoff points as requirements in the numerical detailing, with the goal that the HPFC can be ideally dispatched as a piece of the transmission framework control assets[25-27]

With the expanding significance of BE-SS in micro grids, precise displaying assumes a critical function in understanding their conduct. This work explored and contrasted the exhibition of BESS models and various profundities of detail. In particular, a few models were inspected: a normal model spoke to by voltage sources[28-31]; an ideal dc source behind a VSC; a consecutive buck/support and bidirectional 3stage converter, with all models having a similar control framework and boundaries; and two extra proposed models where the switches were supplanted by subordinate sources to help investigate the distinctions saw in the exhibition of the models.

A). Problem Formulation

The load-voltage of-FBS varies with-change in load &change in source-voltage. There is a need to regulate the load voltage using -closed-loop-control.

The above literature does not deal with enhancement of dynamic-response in HPFC-FBS system utilizing FLC. This exertionrecommends FLC for closed loop control of HPFC-FBS. The organization of the paper is as follows: Section-2 deals with topology of HPFC-FBS. Proposed control-technique for HPFC-FBS is presented in section-3. Simulation results are presented in section-4.

B). Objective: The aim of this exertion is to regulate load voltage of HPFC-FBS by-closed loop-control. This work also involves identification of proper controller for closed loop HPFC-FBS. This research also aims to enhance-dynamic response of HPFC-FBS using the chosen controller.

1. SYSTEM DESCRIPTION

"-Single-line-diagram of the-4bus-MGS-with-HPFC" is outlined in Fig1. The HPFC is located between buses 3 and 4.

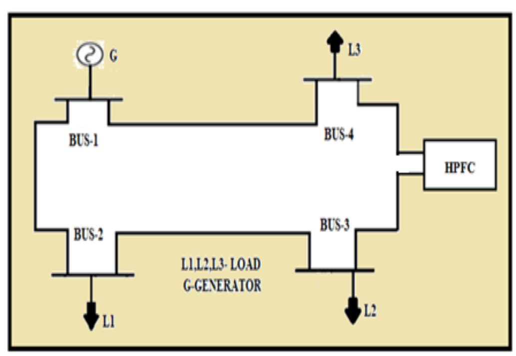

Fig1. –Single-line-diagram of the 4-busMGS with-HPFC

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Block*diagram of closed*loopHPFC4-bus system with HC&Fuzzy*Logic controller isoutlined in Fig 2.

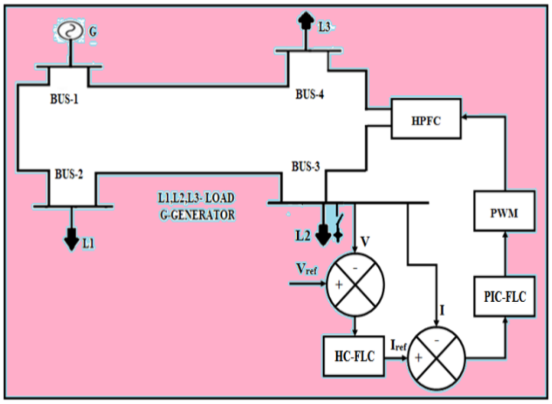

Fig2. -Block-diagram of closed-loopHPFC 4-bus-system with HC-and-FLC

Load*voltage is unrushed& it is allied with the reference*voltage. The voltage error is implied to the voltage Hysteresis controller.The reference current is matched with the actual current and the current error is used to update the pulse width of HPFC.

2. CONTROL TECHNIQUES

3.1 Hysteresis Controller

The hysteresis control approach, being straightforward and quick reaction, delivers every leg exchanging signal for an inverter. The hysteresis regulator creates a sign if the blunder between the reference signal and estimated signal surpasses certain cutoff points as outlined in Fig3. The upsides of the regulator are extremely basic, simple usage practically speaking, and high powerful reactions. It likewise has an inborn current assurance.

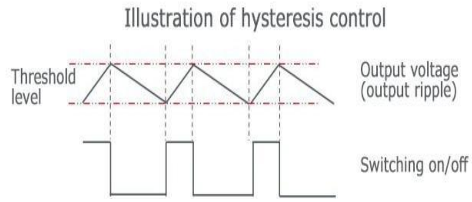

Fig3. Hysteresis-Controller

*3.2 Fuzzy*Logic-Controller*

FL is applied with extraordinary accomplishment in different control relevance. Practically all the shopper items have fuzzy-control. A portion of the models incorporate controlling your room temperature with the assistance of climate control system, against slowing mechanism utilized in vehicles, control on traffic signals, clothes washers, enormous monetary frameworks, and so forth

-Operational-Concepts: Design of a regulator depends on an expected numerical model that looks like a genuine framework. The blunder between genuine framework and its numerical portrayal is determined and on the off chance that it is moderately unimportant than the model is expected to work viably.

An edge consistent that defines a limit for the adequacy of a regulator, additionally exists. The control input is taken care of into both the genuine framework and numerical model. Here, accept x(t) is the yield of the genuine framework and y(t) is the yield of the numerical model. At that point the mistake ϵ(t) can be determined as follows:

$$e(t) = x(t) - y(t)$$

Here, x wanted is the yield we need from the framework and μ(t) is the yield coming from regulator and going to both genuine just as numerical model. The accompanying outline shows how the mistake work is

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followed between yield of a genuine framework and Precise model:

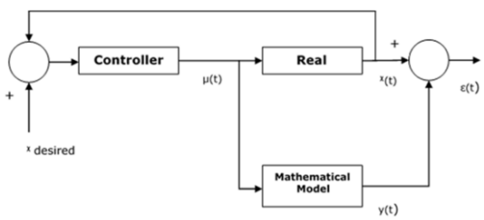

Fig4.*output of a real*system and Mathematical*model

Definition of System: A FL the plan of which depends on the fuzzy numerical model will have the accompanying type of fuzzy guidelines

Rule 1– IF $x_1(t_n)\in X_{11}$AND...AND$x_i(t_n)\in X_{1i}$

Then$\mu_1(t_n)=K_{11}x_1(t_n)+K_{12}x_2(t_n)+...+K_{1i}x_i(t_n)$

Rule 2 – IF $x_1(t_n)\in X_{21}$AND...AND$x_i(t_n)\in X_{2i}$

Then $\mu_2(t_n)=K_{21}x_1(t_n)+K_{22}x_2(t_n)+...+K_{2i}x_i(t_n)$

Rule j– IF $x_1(t_n)\in Xk_1$AND...AND$x_i(t_n)\in Xk_i$

Then$\mu j(t_n)=K_{j1}x_1(t_n)+K_{j2}x_2(t_n)+...+K_{ji}x_i(t_n)$

The above arrangement of boundaries describes the regulator.

System Adjustment: The regulator boundaries are acclimated to improve the presentation of regulator. The way toward computing the change in accordance with the boundaries is the changing component.

Numerically, let θ(n) be a bunch of boundaries to be changed at time t=tn. The change can be the recalculation of the boundaries,

$$\theta^{(n)}=\Theta(D_0,D_1,...,D_n)$$

Here Dn is the information gathered at time t=tn.

Presently this detailing is reformulated by the update of the boundary set dependent on its past incentive as,

$$\theta(n)=\phi(\theta n-1,Dn)$$

3. SIMULATION RESULTS

The point by point MATLAB-simulation of demonstrating and control plan of the regulator are talked about in this segment, taking into account that the dynamic control of the HPFC is acknowledged in the current space. The bus-information and line-information are given in Table-1.1 and Table-1.2 separately.,

TABLE-1.1 : LINE DATA FOR FBS

	Line Impedance	
	Resistance	**Inductance**
bus 1-2	**0.05Ω**	**0.23mH**
bus 2-3	**0.15Ω**	**0.28mH**
Bus3-4	**0.20Ω**	**0.45mH**
bus 1-4	**0.13Ω**	**0.34mH**

TABLE-1.2 : BUS DATA FOR FBS

	Voltage	Load Impedance	
		Resistance	**Inductance**
bus 1	**6.96kv**	**-**	**-**
bus 2	**6.96kv**	**-**	**-**

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bus 3	**-**	**80Ω**	**75mH**
bus 4	**_**	**100Ω**	**80mH**

_Circuit*diagram of open*loopHPFC4-bus system with load*disturbance is outlined in Fig5.

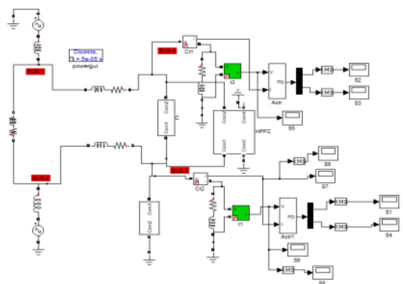

Fig5. _Circuit*diagram of open-loop*HPFC4-bus-system with load_disturbance

Voltage at bus-3 is outlined in Fig 6 and its value is 0.7 *10^4 Volts.

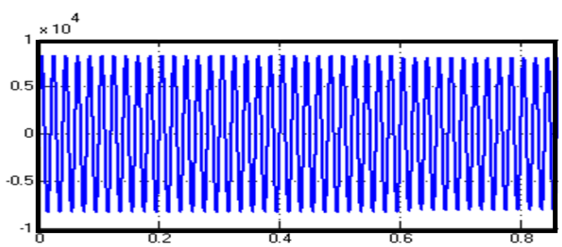

Fig 6. Voltage at bus-3

RMS voltage at bus-3 is outlined in Fig 7. The value of RMS voltage gradually decreases and reaches the steady state error with the value 5750 Volts.

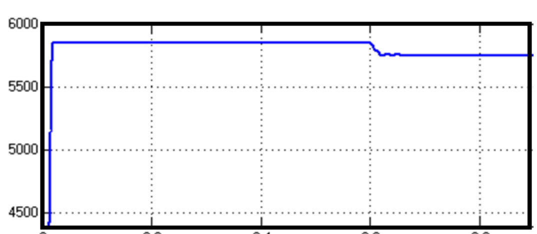

Fig 7. RMS voltage at bus-3

Current at bus-3 is outlined in Fig 8 and its value is 100 Amp.

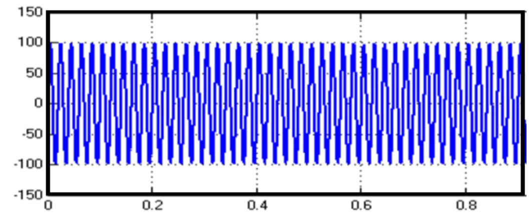

Fig 8. Current at bus-3

RMS current at bus-3 is outlined in Fig 9. The value of RMS current gradually decreases and reaches the steady state error with the value 79.5 Amp.

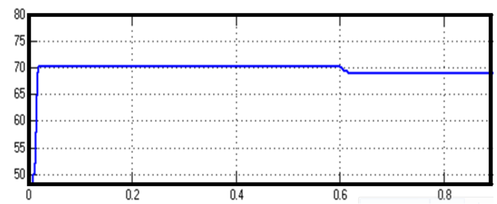

Fig 9. RMS current at bus-3

Real power at bus-3 is outlined in Fig 10. The value of Real power gradually decreases and reaches the steady state error with the value 3.5*10^5 W

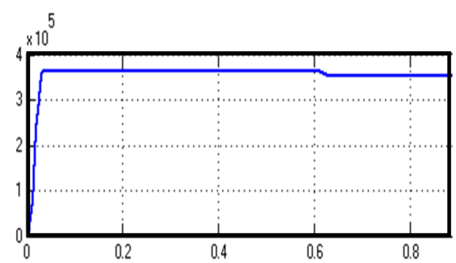

Fig 10. Real power at bus-3

Circuit diagram of closed loopHPFC 4-bus system with Hysteresis controller is outlined in Fig 11.

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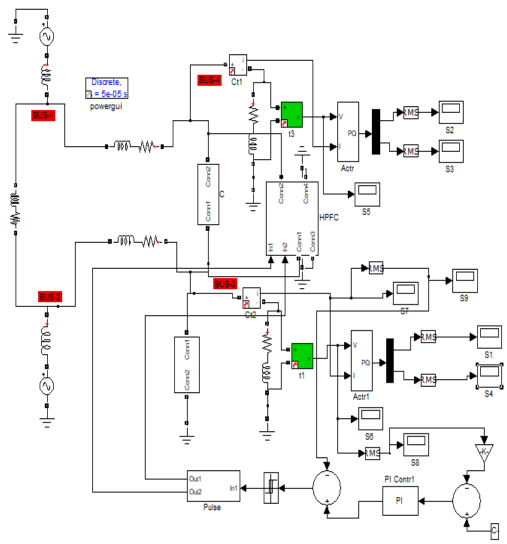

Fig 11. Circuit diagram of closed loop HPFC 4-bus system with Hysteresis controller

Voltage at bus-3 of CL- HPFC-with-HC is outlined in Fig 12 and its value is $1.8*10^4$ Volts

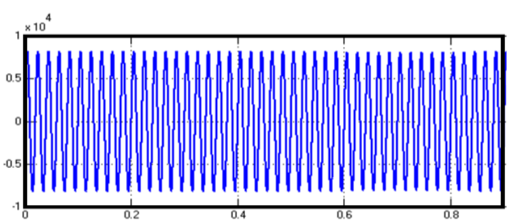

Fig 12. Voltage at bus-3of CL- HPFC-with-HC

RMS voltage at bus-3 of CL- HPFC-with-HCisoutlined in Fig 13 and its value is 5850 Volts.

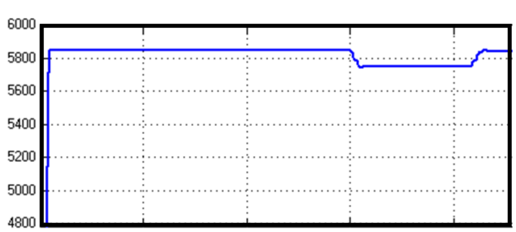

Fig 13. RMS voltage at bus-3of CL-HPFC-with-HC

Current at bus-3 of CL- HPFC-with-HCis delineated in Fig 14 and its value is 100 Amp.

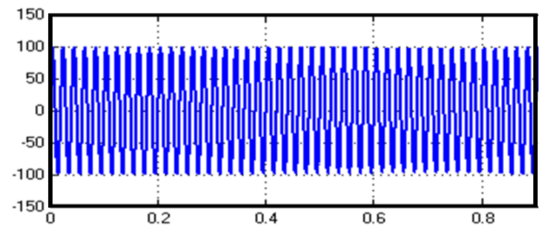

Fig 14. Current at bus-3of CL- HPFC-with-HC

RMS current at bus-3 of CL- HPFC-with-HCis outlined in Fig 15 and its value is 70 Amp.

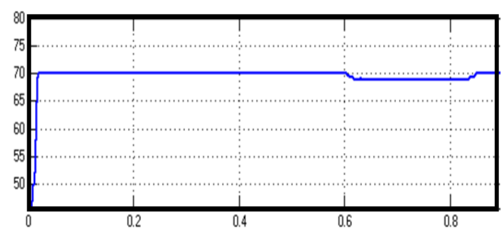

Fig 15. RMS current at bus-3of CL-HPFC-with-HC

Real power at bus-3 of CL- HPFC-with-HCis outlined in Fig 16 and its value is $3.5*10^5$W.

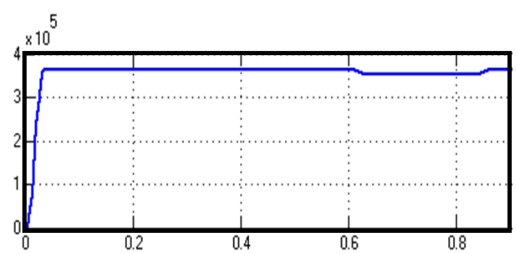

Fig 16. Real power at bus-3of CL- HPFC-with-HC

Reactive power at bus-3 of CL-HPFC-with-HCis outlined in Fig 17 and its value is $10.5*10^4$ VAR.

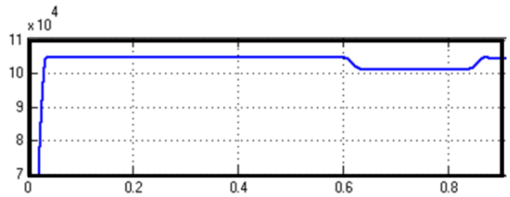

Fig 17. Reactive power at bus-3of CL- HPFC-with-HC

Circuit diagram of closed loopHPFC 4-bus system with Fuzzy Logic controller is outlined in Fig 18.

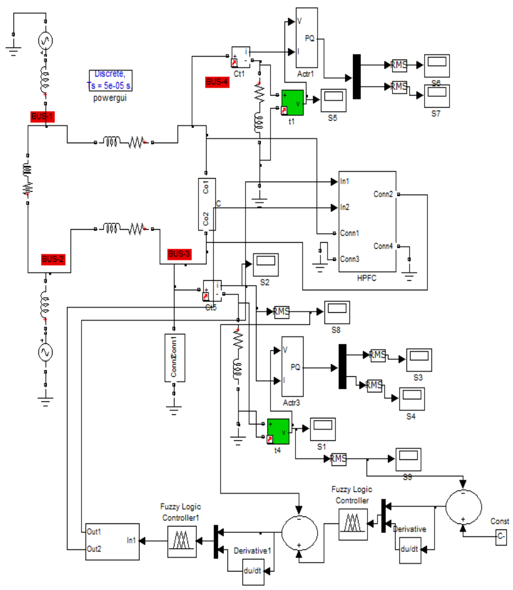

Fig 18. Circuit diagram of closed loop HPFC 4-bus system with FL controller

Voltage at bus-3 of CL- HPFC-with-FLCis outlined in Fig 19 and its value is $1.8*10^4$ Volts

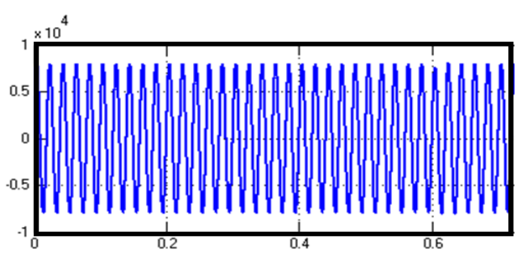

Fig 19. Voltage at bus-3of CL- HPFC-with-FLC

RMS voltage at bus-3 of CL- HPFC-with-FLCis outlined in Fig 20 and its value is 5800 Volts.

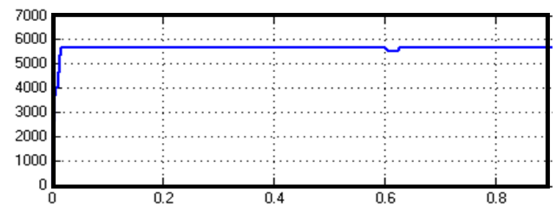

Fig 20. RMS voltage at bus-3of CL- HPFC-with-FLC

Current at bus-3 of CL- HPFC-with-FLCis delineated in Fig 21 and its value is 100 Amp.

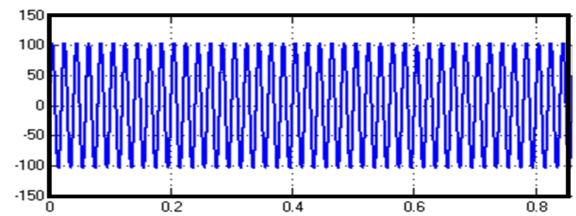

Fig 21. Current at bus-3of CL- HPFC-with-FLC

RMS current at bus-3 of CL- HPFC-with-FLCis outlined in Fig 22 and its value is 70 Amp.

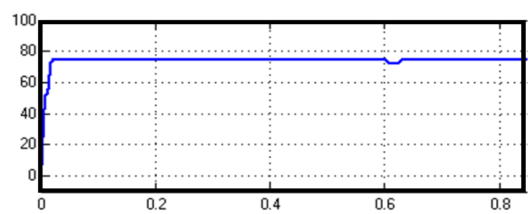

Fig 22. RMS current at bus-3of CL- HPFC-with-FLC

Real power at bus-3 of CL- HPFC-with-FLCis outlined in Fig 23 and its value is $3.5*10^5$ W.

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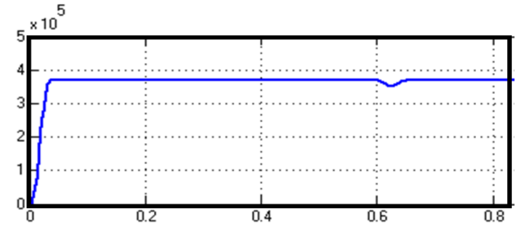

Fig 23. Real power at bus-3of CL- HPFC-with-FLC

Reactive power at bus-3 of CL-HPFC-with-FLCis outlined in Fig 24 and its value is 10.5*10^4 VAR.

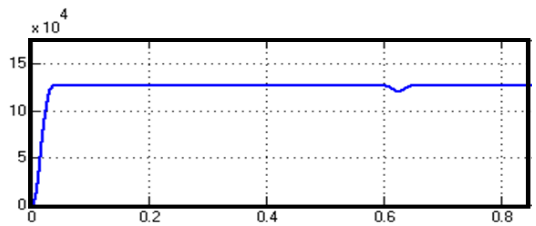

Fig 24. Reactive power at bus-3of CL-HPFC-with-FLC

Comparison of time domain parameters (voltage) using HC & FLCis given in Table-3. By using FLC, the rise*time is abridged from 0.61Sec to 0.60 Sec; the peak*time is abridged from0.78 Sec to 0.61 Sec;the settling*time is abridged from0.86 Sec to 0.63 Sec; the steady*state*error is abridged from 1.5 V to 0.7 V. Bar-chart-Comparison of time*domain-parameters (voltage) is given in Fig25.

TABLE -3COMPARISON OF TIME DOMAIN PARAMETERS (VOLTAGE) USING HC AND FLC

Type of controller	$T_{r(Sec)}$	$T_{p(Sec)}$	$T_{s(Sec)}$	$E_{ss(Voltage)}$
HC	0.61	0.78	0.86	1.5
FLC	0.60	0.61	0.63	0.7

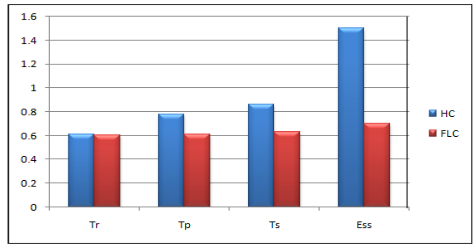

Fig 25 _Comparison of time*domain*parameters (voltage) using HC-and-FLC

Comparison of time domain parameters (current) using HC & FLCis given in Table-.4. By using FLC, the rise*time is abridged from 0.63 Sec to 0.60 Sec; the peak*time is abridged from0.80 Sec to 0.61 Sec;the settling*time is abridged from0.87 Sec to 0.62 Sec;-the steady*state*error is abridged from 0.9 Amp to 0.1 Amp. Bar-chart-Comparison of-time domain-parameters (-current) is given in Fig 26.

TABLE -4 _COMPARISON OF-TIME-DOMAIN--PARAMETERS (CURRENT) USING-HC ANDFLC

Type of controller	$T_{r(Sec)}$	$T_{p(Sec)}$	$T_{s(Sec)}$	$E_{ss(Amp)}$
HC	0.63	0.80	0.87	0.9
FLC	0.60	0.61	0.62	0.1

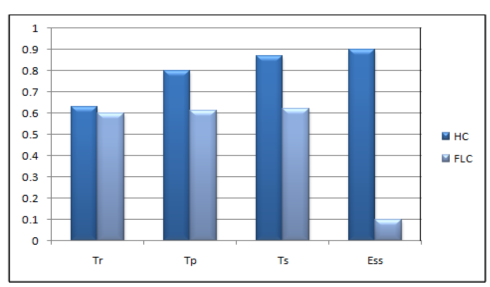

Fig 26.Comparison of time domain parameters (current) using HC and FLC

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4. CONCLUSION

Open*loop system and closed*loopHPFC 4bus-system with Hysteresis controller and Fuzzy Logic Controllersare simulated. Simulation is done and the outcomes are compared in terms of rise*time, peak*time, settling*time and Steady*state*error. By using FLC, the rise*time is abridged from 0.61 Sec to 0.60 Sec; the peak*time is abridged from 0.78 Sec to 0.61 Sec;the settling*time is abridged from 0.86Sec to 0.63Sec;the steady*state*error is abridged from 1.5V to 0.7 V. The outcomes represents that the Closed-loop-HPFC-Four-bus system with Fuzzy Logic controller is superior to the Closed-loop-HPFC-Four-bus system with Hysteresis controller. The-simulation-outcomes represent the ability of the H.P.F.C in improving the power-qualityusing Fuzzy Logic controller.

The Scope of present work deals with closed loop HPFC 4bus-system with HysteresisController and Fuzzy Logic controller. Closed loop HPFC 4bus-system withSlide Mode controller can be done in Future.

REFERENCES

1. -ZhangL, -LiY. –Optimalenergymanagement-of hybridpowersystem-with-twoscaleddynamic programming”, -PowerSystemsConferenceExposition(PS-CE), -2011-IEEE/-PESpp18Mar2011
2. -BiswasI, -DashV, -BajpaiP. –Sizing-optimization-of PV-FC-battery-system-with-hybrid-PSO-EO- algorithm-IEEE-AnnualIndia-Conference(pp869 874 , Dec-2012.
3. -BehzadiMS,-NiasatiM.-Comparative-performance –analysis-of-a-hybridPV/FC/battery-standalone-system using-different-power-management-strategies-and -sizing-approaches ”, -InternationalJournal-of Hydrogen-Energy , Vol.40 , 1 pp 538 548 , 2015
4. -RandaKallel,-GhadaBouettaya,-LotfiKrichen , -Control-Management-Strategy-of-StandAlone-Hybrid Power-Micro-System-using-Super Capacitor”---Capacitor”, -International-journal-of-Renewable Energy-Research-Vol4, -No1,-pp210 213, -2014
5. -Kohsris-,Plangklang-B.B., “-Energy-management-and-control-system-for-smart-renewable-energy -remote-power--generation”, -Energy-procedia-Vol9 , -198 206 , -2011.
6. –Bouthaina-Madaci,-RachidChenni,-ErolKurt, KamelEddineHemsas , -Design-and-control-of-a-stand-alone-hybrid-power-system”,-International- Journal-of-Hydrogen-EnergyVol41,29pp12485-2496, -2016
7. -MirazimiSJ,-FathiM. –Analysisofhybrid-windfuel cell/batterydiesel-energysystem-underalaska condition ”, -InternationalConference-onElectrical Engineering/-ElectronicsComputerTelecommunicationsandInformationTechnology (ETI-CON)pp917-9 20May2011.
8. -JayalakshmiN.S.,-D.N.Gaonkar, -PramodBhatNempu–Power-Control-of-PV/Fuel-Cell/Super-capacitor Hybrid-System-for-Stand-Alone-Applications ”, International-Journal-of-Renewable-Energy-Research Vol6No2pp672 679,-2016
9. -SG.-Malla, -C.N.-Bhende , -Voltage-control –of-standalone-wind-and-solar-energy-system ”, -Electrical-Power-and-Energy-Systems-Vol56pp361 373 , -2014
10. -T.Vigneysh,-N.Kumarappan ,-Autonomous-operation -and-control-of-photovoltaic/solid-oxide-fuel cell/battery-energy-storage-based-microgrid-using fuzzy-logic-controller ”, -International-Journal –of-Hydrogen-Energy 41, -No3, -pp1877 -1891, -2015
11. -ZengQingrong,-ChangLiuchen ,-An-advanced SVPWM-based-predictive-current-controller-for-three phase-inverters-in-distributed-generation-systems ”, -IEEE-Transactions-on-Industrial-ElectronicsVol55 , No3 , -1235-12 46 ,-2008
12. -ChenZhiyong-LuoAnWangHuajun,ChenYandong, LiMingshen,-HuangYuan. –Adaptiveslidingmode voltagecontrol-forinverteroperating-inislandedmode-inmicrogrid ”,-InternationalJournalofElectricalPower-EnergySystem,-Vol66pp.-133-1 43 , -2015
13. -WangFuCheng,-Kuo-Po-Chen, -Chen-HsuehJu.Ju., -Control-design-and-power-management-of-a -stationary-PEMFC-hybrid-power-system-International Journal-of-

July – August 2020
ISSN: 0193-4120 Page No. 6517 - 6527

Hydrogen-EnergyVol38No14pp5845-5856 , -2013

14. -HassanMA, -AbidoMA., “-Optimal-design-of-micro grids-in-autonomous-and-grid-connected-modes-using -particle-swarm-optimization”,-IEEE-Transacti-on Pow-Electronics, Vol26No 3pp755 769, -2011
15. -AlSaediWaleed,-LachowiczStefanW, -HabibiDaryoush,-Bass-Octavian, “-Power-flow -control-in-grid-connected-microgrid-operation-using particle-swarm-optimization-under-variable-load conditions”, -International-Journal-of-Electrical-Power-Energy-Systems Vol49pp76 85, 2013.
16. -WuXiaoJuan,-Huang-Qi,-Zhu-XinJian, “-Power-decoupling-control-of a solidoxide-fuel-cell-and-micro gas-turbine-hybrid-power-system”,-Journal-of-Power -Sources , -196, No3, pp1295 1 302, -2011.
17. -AhmadShameem,-AlbatshFadiM, -MekhilefSaad, -MokhlisHazlie, “-Fuzzy-based-controller-for-dynamic –Unified-Power-Flow-Controller-to-enhance-power transfer-capability”,-Energy-Conversion-Management , Vol79pp652- 6 65, -2014.
18. -MohammadRM,-Mohd-FR,-Ali-AG,-Mohd-WM., “-Control-techniques-for-three-phase-four-leg-voltage source-inverters-in-autonomous-microgrids:-a -review”, -Renewable-Sustainable-Energy-Reviews, Vol54 pp1592-610, -2016.
19. -W.Ziqi,-C.Jinfu,-Z.Guofang-etal., "-Optimal-power -flow-calculation-with-moth-flam-optimization-algorithm", -*Power-Syst-Technol.*, vol41no11pp3641-3647, -2017.
20. -QR.Hao-JF.-Man,-F.Gao and -MY. -Guan, "-Voltage -limit-control-of-modular-multilevel-converter-based unified-power-flow-controller-under-unbalanced-grid -conditions", -*IEEETrans.-PowerDel.*,-vol33no3pp 1319-1327Jun.2018.
21. -PCSong, -ZXu and -HF.-Dong, "-UPFC-based-line overload-control-for-power-system-security -enhancement",- *IE-T Gener.-Transm.-Distrib.*, -vol11 no13pp.3310-3317Aug.2017.
22. -FZPeng,-YLiu, -ST.-Yang,-SZhang,-DGunasekaran and-UKarki, "-Transformer-less-unified-power-flow controller-using-the-cascade-multilevel-inverter", -*IEEETrans.-PowerElectron.*,-vol31no8pp5461-5472Aug2016.
23. –JDLiu-and-VDinavahi, "-Nonlinear-magnetic -equivalent-circuit-based-real-time-Sen-transformer electromagnetic-transient-model-on-FPGA-for-HIL -emulation", -*IEEETrans.-PowerDel.*,-vol31no6pp2483-2493, -Dec2016.
24. -BC.-Chen, -WLFei,-JXYuan-and-CHTian, "-Research-on-an-improved-hybrid-unified-power-flow controller", -*Proc.-IEEE-Energy-Convers-Congr. Expo.*, -pp1296-1303, -2017.
25. -FZ.-Peng,-Y.Liu,-S.-Yang,-S.Zhang,-D.Gunasekaran and-U.Karki, "-Transformer-less-unified-power-flow controller-using-the-cascade-multilevel-inverter", -*IEEETrans.-PowerElectron.*, -vol31no8pp1077-1084, -Aug2016.
26. -Tamimi,-CA.-Cañizares-and-CBattistelli, "-Hybrid power-flow-controller-steady-state-modeling-control and-practical-application", -*IEEETrans.-PowerSyst.*, vol32no2pp1483-1492Mar2017
27. -B.Tamimi, "-Modeling-and-control-of-the-hybrid power-flow-controller-for-steady-state-and-dynamic studies-and-applications",-Dec2017,-[online] Available: http:-//hdl.handle.net/10012/12750.
28. -MFarrokhabadi,-SKoenig,-CACañizares,-KBhattacharya-and-TLeibfried, "-Battery-energy –storage-system-models-for-microgrid-stability-analysis-and-dynamic-simulation", -*IEEE-Trans. Power-Syst.*, vol32no5pp1-13Aug2017.
29. -XFeng and -XZheng, "-A-modular-multilevel-power flow-controller-for-multi-terminal-HVDC -systems", -*Autom.-Electr. -PowerSyst.*, -vol39no3pp95-102, -2015.
30. -M.JCarrizosa, -F.DNavas, -.Damm-etal., "-Optimal –power-flow-in-multi-terminal-HVDC-grids-with offshore-wind-farms-and-storage-devices",- *Int.J. Electr.-Power-Energy-Syst.*, -vol65pp291-298, -2015.
31. "-Solar-eclipse-readiness",-Aug2017, [-online] -Available:- http://www.caiso.com.