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Design of Aacc for Cascade Dc Power System to Improve the Stability with Fuzzylogic Controller

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Abstract: **The fundamental configuration of the dc distributed power system (DPS) is cascade connection of converters. In cascaded system impedance problem occurs due to independent design of converters and may make the system unstable. In the previous strategies to minimize impedance problem they have adopted alteration of the converters at both source and load end. In this paper a new method of mitigating impedance problem which is in parallel with the cascaded system's middle bus and it just needs to know the bus voltage with all the existing sub-systems remained same. The AACC acts as a proportional bus capacitor to mitigate the converter impedance at source side. In this method FUZZYLOGIC CONTROLLER is used to improve the stability. Due to the bus capacitor of the loss of force is minimized. The dynamic response of the system is also enhanced compared to normal capacitor. Since this system requires no electrolytic condenser the cascaded system's lifetime is drawn out. In this paper, a 480Wcascaded system with fuzzy logic controller is built and performance is studied. And the results are verified by using MATLAB/SIMULINK.**

1. INTRODUCTION

The flexible system design, good energy conversion efficiency, and tremendous power deliver capability of dc DPS make it presence in many areas such as Defense, Research and Industries [1]-[6]. Modularity design is one of the good attributes of dc DPS in which every subsystem is initially designed exclusively. System's advancement cycles and expenses are successfully reduced with modulization model of DPS [7]. It was additionally called attention to that if both the converters at sending end and load are stable exclusively, Zo<Zin in the Varity of frequencies, the cascaded system stability will be assured. The method is alleged Center brook model. Hence, different impedance criteria going for a more precise and down to earth expectation of the subsystem collaboration had been created in the most recent two decades [8].

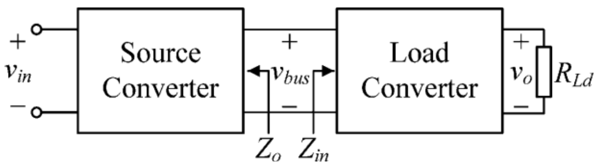

Fig.1. Cascaded power supply system

Answers for tackling the instability issue are suggested and can be extensively ordered into passive and active strategies. Passive systems utilize passive parts like R, L and C to enhance framework stability. A R-load was added to alter dynamic qualities of load and in this manner enhancing framework performance [9]. Both R-C and R-L dampers were familiar with minimization of the output impedance peak of the converter at source end, which ensures $Z_{o<}Z_{in}$ in the whole range of frequencies.. Active techniques for balancing out the framework are focused around adjusting the control of the converters at source and load end or including a power cradle amid the sending and load subsystems. The previous methodology, then again, is typically intricate in usage and in some cases clashing with other control goals. In the last method, the power cushion is joined in arrangement in the middle of the sub-systems, and it influences the Z connection that may not be adequate in a few applications [10].

All the previously stated arrangements are required to change the inside configuration, which also includes the principle AND/OR control circuits, of the sub-systems of dc DPS, prompting upgrade of the sub-systems that have as of now been separately composed. This negates with the destination of the measured quality outline of dc DPS and expands the framework's improvement cycles.

In this paper, an Adaptive Active Capacitor Converter (AACC) FUZZY logic controller is arranged and shunted with the middle bus of the cascaded system is presented [1]. The difference between AACC and an adaptive bus capacitor is the output power cascaded-system that decreases the Zo of the converter at source end to abstain from associating with Zin of the converter at load side. As an issue, the cascaded-system gets to be steady. The AACC just needs to distinguish the moderate V_{bus} with no alternation of the current sub-systems; consequently, it acts as an issue stabilizer for dc DPS. In the mean time, the proportional condenser of the AACC is suitable, guaranteeing a negligible extra power misfortune and a finer element reaction of the system than that utilizing a detached condenser. Moreover, as no condenser of electrolyte type is needed in the AACC, the cascaded system's life-time is delayed. In the present paper we are utilizing a fuzzy logic controller rather than pi controller to enhance the stability.

II. INSTABILITY PROBLEM OF CASCADED SYSTEM

The cascaded-system shown in Figures (1) and (2) will be unstable if Z_o is converged with Z_{in} and f_{cs} is short of what f_{c_L}, For this situation, the oscillating frequency is f_{c-s} which is independent of system's power. The above examination shows that Z_o is independent of P_o, and when $f < f_{c\_L}$, the extent of Z_{in} is contrarily relative to P_o. In this way, the cascaded-system is destined to be un-stable at rated load in light of the fact that Z_{in} is negligible and effortlessly crossed with Z_o at this condition. Note-that the above concluded points are general and material to all DC-DC converters [11].

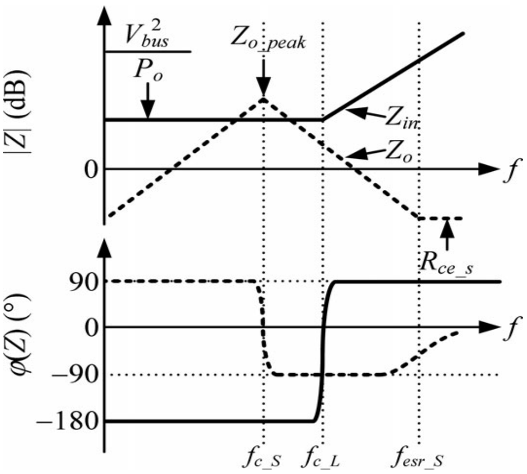

Fig.2.Graphical representation of effect of Impedance in cascaded system

There is nothing more attractive than an aggregate detachment in the middle of Z_o and Z_{in} to guarantee to the cascaded-system is steady. Since source converter 's output capacitor is defiantly $|Z_{o\text{-peak}}|$, one natural route is to decrease the source converter' output impedance by including a halfway transport capacitor C_{bus} to the cascaded system, as demonstrated in Figure3. Here, C_{bus} can be dealt with as an extra output filter condenser of the sending end converter, and the proportionate L-C output Z model of source converter with C_{bus}.

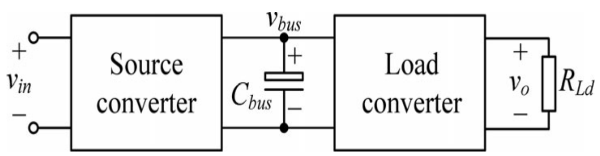

Fig .3. Intermediate bus system of cascaded system

A bigger C_{bus} brings about a littler band-width of the sending-end converter that is as of now separately planned, prompting a poor dynamic execution. Since the obliged C_{bus} is moderately expansive, it unavoidably embraces electrolytic capacitor, demonstrating a critical lessening of the lifetime. To conquer this poor dynamic execution we are utilizing Versatile Dynamic Capacitor Converter with PI controller. The basic components of AACC are Q_{A1} and Q_{A2} switches, inductor L_a, and condenser C_a. By varying value of La properly, transport area of AACC will exhibit an adaptively fluctuating C_{bus} which guarantees solidness of the cascaded-system in the whole load run and active response is also enhanced. For the cascaded-systems with different load converters also AACC is applicable. Fin this case the AACC has the similar process guideline as structure of Figure.4, which reduces source converter's Z_o lower than impedance of the aggregate information of the various converters at load end [12].

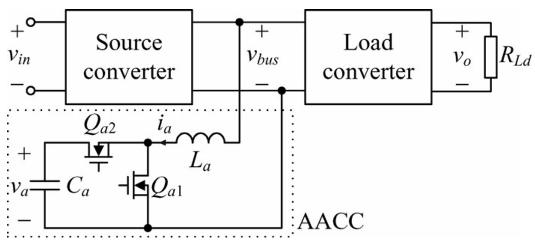

Fig. 4. Cascaded system with AACC

In cascaded system AACC with PI controller having distortions and the settling time is more, to overcome this we are adopting FUZZY logic controller instead of PI controller.

III. PROPOSED AACC WITH FUZZY LOGIC CONTROLLER

A. *DESIGN OF AACC OUTPUT FILTER CAPACITOR C_A*

In AACC, when switching harmonics are ignored for the bus voltage and current of the cascaded system's and can be expressed as

$$ia(t) = C_{bus}(Dv_{bus}/dt) \quad (1)$$

$$v_{bus} = V_{bus} + \Delta V_{bus\_allow} \sin \omega t \quad (2)$$

Where Vbus is the average value of vbus, and ω is the angular frequency of the ripple in V_{bus}, i.e.,

$$\omega = 2\pi f_c S.$$

The instantaneous input power of AACC can be obtained by (1) and (2), i.e.,

$$P_a(t) = v_{bus} i_a =$$

$$(V_{bus} + \Delta V_{bus\_allow} \sin \omega t) C_{bus} \Delta V_{bus\_allow} \omega \cos \omega t \quad (3)$$

Generally $\Delta V_{bus\_allow} - V_{bus}$; thus, (3) can be expressed as

$$P_a(t) = V_{bus} \Delta V_{bus\_allow} \omega \cos \omega t . \quad (4)$$

From the equations (1) and (4), the instantaneous P_{in}, i_A, and V_a waveforms of AACC are shown in Figure. 5. It can be derived that discharging of C_a starts from T_{os} /4 to $3T_{os}$ /4, and V_a decreases and charging of Ca starts from 3Tos /4 to 5Tos /4, and Va increase. Due to this peak and least value of V_a occur at T_{os}/4 and $3T_{os}$ /4 respectively .

The power charge of C_a from 3Tos /4 to 5Tos /4 is given by

$$\Delta E_a(t) = \int_{\frac{3T_{os}}{4}}^{t} P_a(t)dt$$

$$= \int_{\frac{3T_{os}}{4}}^{t} V_{bus}C_{bus}\Delta V_{bus\_allow}\omega\cos\omega t dt$$

$$= 2V_{bus}C_{bus}\Delta V_{bus\_allow}\sin^2\left(\frac{\omega}{2}t - \frac{\pi}{4}\right) \quad (5)$$

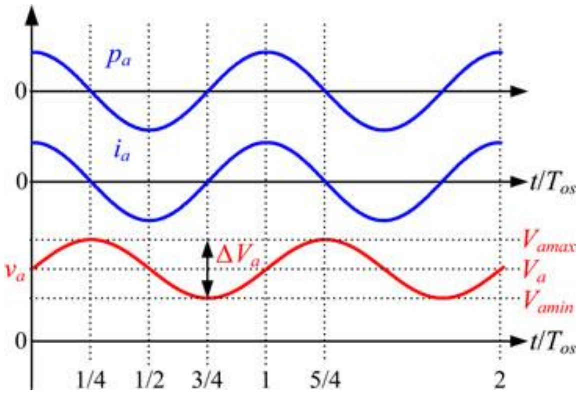

Fig. 5. Waveforms of instantaneous P_{in}, L_a, and V_a of the AACC.

And ΔE_a (t) is given by

$$\Delta E_a(t) = \frac{1}{2}C_a v_a^2(t) - \frac{1}{2}C_a V^2_{a\min} \quad (6)$$

Where V_{amin} = minimum voltage of the condenser C_a, substituting (5) in (6) gives

$$\frac{1}{2}C_a\left[v_a^2(t) - V^2_{a\min}\right] = 2V_{bus}C_{bus}\Delta V_{bus\_allow}\sin^2\left(\frac{\omega}{2}t + \frac{\pi}{4}\right) \quad (7)$$

Since (13)

$$v_a(t) = \sqrt{\frac{4V_{bus}C_{bus}\Delta V_{bus\_allow}\sin^2\left(\frac{\omega}{2}t - \frac{\pi}{4}\right)}{C_a} + V^2_{a\min}} \quad (8)$$

Substituting $t=5T_{os}/4$ into (14), the Peak voltage of condenser C_a be able to be given like

$$V_{a\max} = \sqrt{\frac{4V_{bus}C_{bus}\Delta V_{bus\_allow}}{C_a} + V^2_{a\min}} \quad (9)$$

The average voltage of C_a can be approximated as

$$V_{adc} = \frac{(V_{a\min} + V_{a\max})}{2}$$

$$= \frac{(V_{a\max} + \sqrt{\frac{4V_{bus}C_{bus}\Delta V_{bus\_allow}}{C_a} + V^2_{a\min}})}{2} \quad (10)$$

For assurance of good process of AACC, the C_a's immediate voltage has to be higher than the V_{in} of AACC, which is given as

$$v_a(t) \geq V_{bus}$$

We keep V_{amin} = V_{bus} and $\Delta Vbus_{\_=}$ at 1%*V_{bus}, and the normalized V_{amax} and V_{o_dc} with base of V_{bus} are

$$V^*_{a\max} = \frac{V_{a\max}}{V_{bus}} = \sqrt{\frac{4\%}{C_a} + 1} \quad (11)$$

$$V^*_{adc} = \frac{V_{adc}}{V_{bus}} = \frac{1}{2} + \sqrt{\frac{1\%}{C_a} + \frac{1}{4}} \quad (12)$$

We know that C^*_a is normalize C_a with bottom of C_{bus}

From the equations (11) and (12), V_a^* (max) and Va*(dc) as function of C^*_a are drawn in Figure. 8, Where V_{amax} increase with reduction of C_a. To take layer capacitors or clay capacitors in the place of electrolytic condensers, the charge of C_a has to be small enough. This will give elevated V_{amax} which results in elevated voltage pressure on Q_{a1} and Q_{a2}. Hence Ca have to be chosen at rated weight as it is the most horrible situation for the cascaded-system and having necessary peak value C_a.

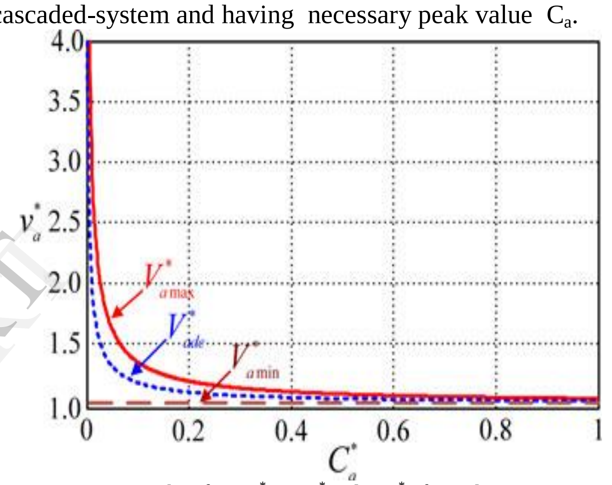

Fig.6. Graphs of V_{amax}^*, V_{amin}^* and V_{adc}^* of Condenser C_a

B. SLECTION OF Q_{A1} AND Q_{A2}

From the Figure (4), the peak value of Qa1 and Qa2 is the voltage-stress V_A,

i.e. $V_{Qa1} = V_{Qa2} = V_{a\max}$ (13)

The rated current of L_a of Q_{a1} and Q_{a2} is the current-stress, and be able to be find out from (1) and (2),

i.e. $I_{Qa1} = I_{Qa2} = \omega C_{bus\max}\Delta V_{busallow}$ (14)

Where $C_{bus-max}$ at rated-load C_{bus} is the desired value. The power devices for Q_{a1} and Q_{a2} are selected based on (13) and (14).

C. AACC's INDUCTOR

Two things have to be taken into account when selecting the L_a value. One is ensuring the current through inductor is able of track the I ref, and inductor current will keeps small for second ripple. Here the AACC's inductor current I_a requires to path the oscillating wave, whose oscillating frequency is the cutoff-frequency of voltage loop gain of sending end converter. The oscillation frequency f_{cs} is more than switching frequency f_{sa} of AACC. Assurance of tracking speed of Ia and will be enough to prefer the value of L_a by single concern specified to the inductor current ripple. As the two control switches of AACC function in a balancing mode, the AACC is in service in incessant current conduction form.

Hence the duty cycle of Q_{a1} is

$$dQ_{a1}(t) = 1 - V_{bus}.\ V_a(t) \quad (15)$$

When Q_{A1} is turned ON and Q_{A2} is turned OFF, the voltage across L_a is V_{bus}. This voltage causes I_a to increase. The ripple of i_a can be expressed as

$$\Delta i_{La} = V_{bus} L_a \cdot dQ_{a1}(t) \cdot f_{sa}. \quad (16)$$

Substituting equation (22) in equation (23) results as

$$L_a = (V_a(t) - V_{bus} V_a(t) \Delta i L_a f_{sa} \quad (17)$$

From the above equation the oscillation period which L_a varies with $V_a(t)$.

IV. FUZZY LOGIC CONTROLLER

The fuzzy logic controller (FLC) [13] dissimilar to the crispy-logic in the Boolean theory that uses just two logic levels (0 to 1), is an extension of logic that concedes unending logic levels (from 0 to 1), to take care of an issue that has vulnerabilities or uncertain circumstances. Once more, a fuzzy control is a methodology control that is focused around fuzzy logic and is ordinarily portrayed by "IF-THEN" runs the show. The configuration of the proposed FLC is portrayed in the accompanying.

A. FUZZIFICATION

The Fuzzification methodology comprises of discovering fitting membership functions to depict crisp information. For the outline of the anticipated FLC, departure of pace of synchronous generator and firing angle of thyristors are chosen as the input & output, individually. Triangular membership functions are indicated in Figure. 5, in which the phonetic variables N, Z, and P stand for negative, zero, and positive, separately. The membership functions are controlled by the experimentation method so as to get the better framework execution. The mathematical statement of the triangular membership capacity used to focus the evaluation of membership in which the estimation of evaluation of membership, " is the width, " is the direction of the time when the evaluation of membership is 1 and " is the estimation of the input variable.

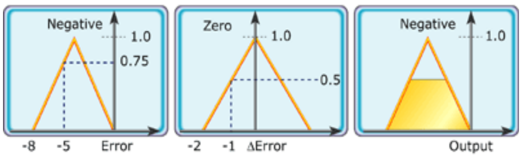

Fig.7. Membership function

B. FUZZY RULE BASE

The heart of a fuzzy controller is the rule base as the control technique is used for controlling the closed-loop system is put away as an issue of control rules. The particular gimmick of the proposed fuzzy controller is its extremely basic configuration containing two variables. The utilization of the single–input single–output (SISO) variable makes the fuzzy controller exceptionally direct. Fig. 7 demonstrates the membership functions for the output variable comprising of three singleton fuzzy sets Little, MEDIUM, and Enormous. The control rules of the anticipated controller are resolved from the perspective of commonsense system operation and by experimentation and are demonstrated in Table-I.

Table-I: rule base of FLC

Error alteration	-Ve	Zero	+Ve
-Ve	More -Ve	Negative	Zero
Zero	Negative	Zero	Positive
+Ve	Zero	Positive	More +Ve

C. FUZZY INFERENCE

The essential working principle of the deduction motor is it induces, i.e. it finds a sensible solution. Really, the surmising motor is a system which utilizes the rule base and the input data of the controller to make the determination. The finish of the derivation motor is the fuzzy output of the controller, which therefore turns into the input to the defuzzification interface. For the derivation system of the anticipated FLC, Mamdani's-technique [10] is used. A fuzzy rule normally has an IF-THEN arrangement as takes after: IF IS And IS THEN where and are fuzzy input variables, is the fuzzy output variable, is the rule number, is the aggregate number of rules and are fuzzy subsets in the universe of talks , and , individually. Consequently, as indicated by Mamdani, the level of similarity, of every fuzzy rule is as per the following: where and are the estimations of the evaluation of membership.

D. DEFUZZIFICATION

In the previous operation, the fuzzy finish of the induction motor is defuzzified, i.e. it is changed to a crisp signal. The last signal is the last result of the FLC, which is obviously, the crisp control signal to the procedure. The inside of-range system is the most well-known and rather basic defuzzification strategy which is actualized to focus the yield crispy worth. This is given by the accompanying statement: where is the crispy yield work and is now characterized in the past area. To perceive how compelling the fuzzy controlled Fell system in enhancing the stability and its execution is contrasted with that of a traditional PI controlled Fell System plan.

V. SIMULATION RESULTS AND DISCUSSIONS:

Design of AACC for a cascaded-system is discussed here. The system is consisted of two phase-shifted full-converters of full-bridged type as shown in figure.9. The parameters of both the converters at sending end and load can be derived from the table.

Table-II: parameters of source converter Load converter

Parameters	Values
Winding turn ratio of T_{r1}	5:1
Lf1	150µH
Cf1	680µH
Lr1	2µH

Table-III: parameters of load converter

Parameters	Values
Winding turns ratio Tr2	3:1
Lf2	2.2μH
Cf2	4700μH
Lr2	1μH

A. CASCADED SYSTEM WITH AACC

The simulation model of the Cascaded system with AACC of PI controller is shown below figure. The input 360V is given the source converter, and the transformer step downs this voltage as 5:1 ratio of 72V. And the voltage is minimized as 48V with PI controller. This output voltage is given as the input to the load converter. The load converter is also step down the voltage as 3:1 ratio and the output is 12V. The resistive load of 480Ω is connected at the end of load converter which gives load current and will be less compares with the passive method.

B. CASCADED SYSTEM WITH AACC AND FUZZY LOGIC CONTROLLER

The simulation model of the Cascaded system with AACC of FUZZY controller is shown below figure. The input 360V is given the source converter, and the transformer step downs this voltage as 5:1 ratio of 72V. And the voltage is minimized as 48V with PI controller. This output voltage is given as the input to the load converter. The load converter is also step down the voltage as 3:1 ratio and the output is 12V. The resistive load of 480Ω is connected at the end of load converter which gives load current and will be less compares with the AACC of PI controller method.

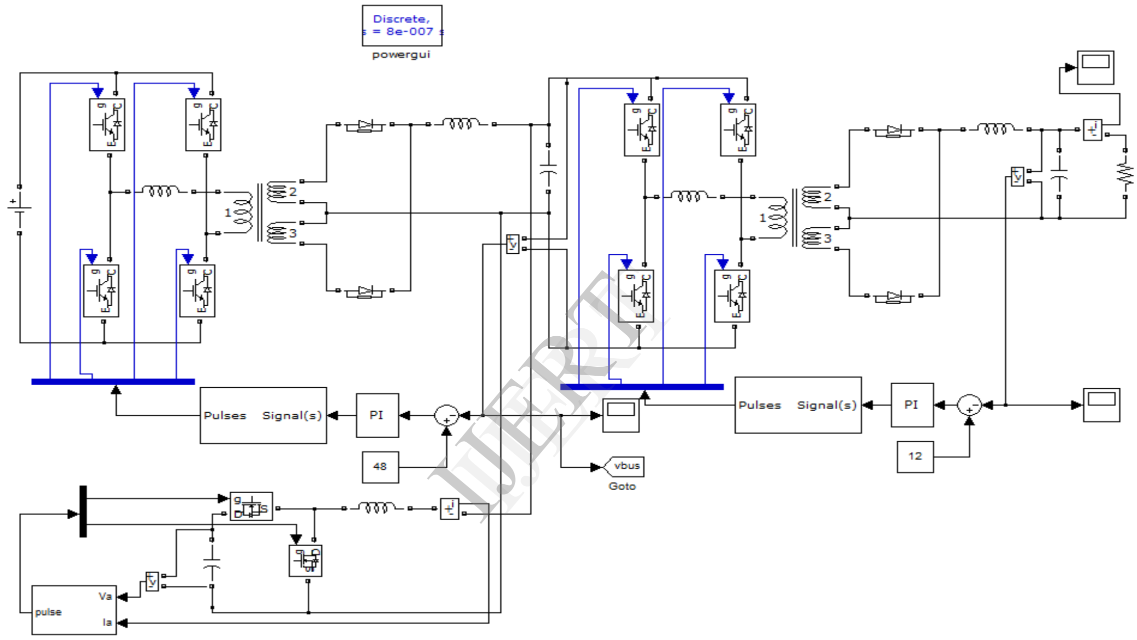

Fig.8. Cascaded system with AACC and PI controller

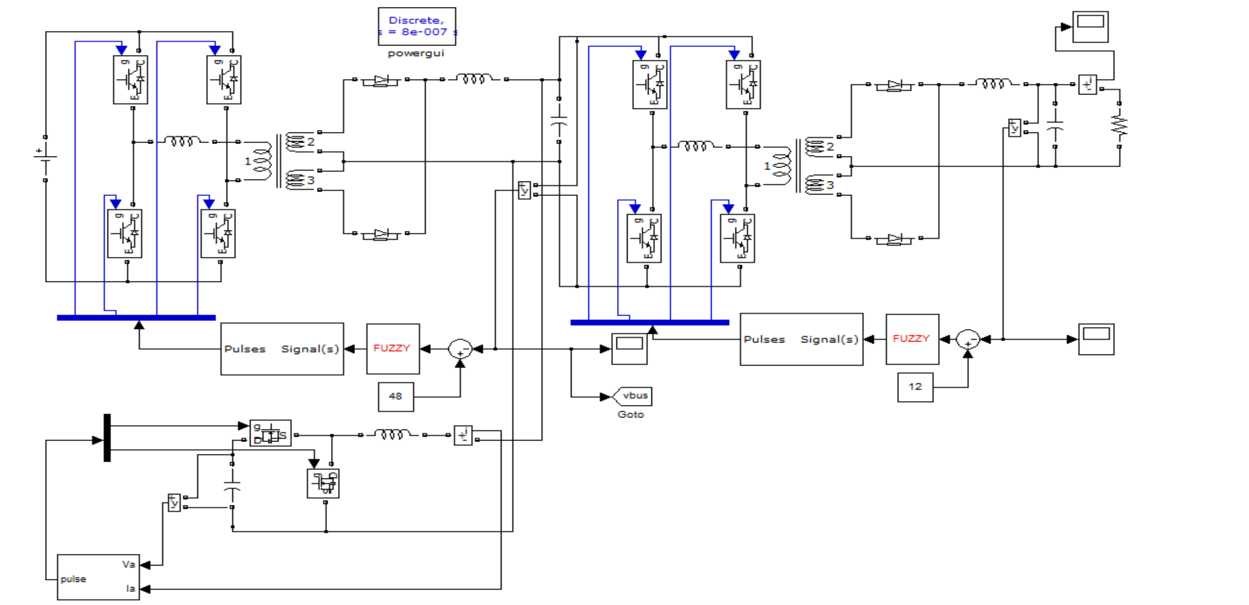

Fig.9. Cascaded system with AACC and FUZZY controller

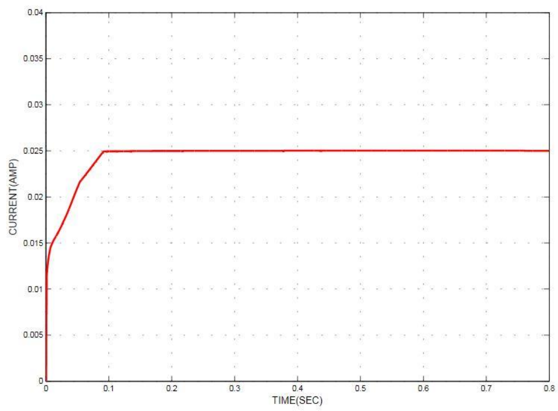

Fig.10. output current of cascaded system with AACC and PI controller

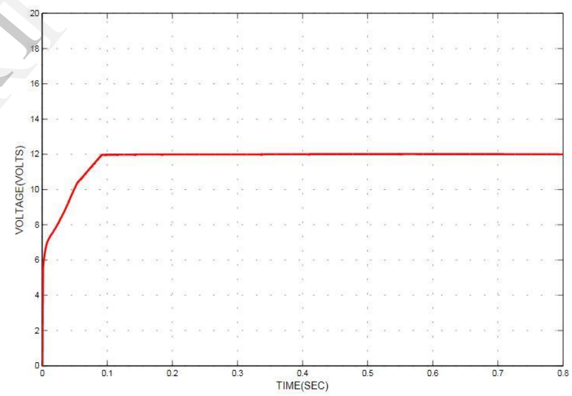

Fig.12. Vo of cascaded-system with AACC and PI controller

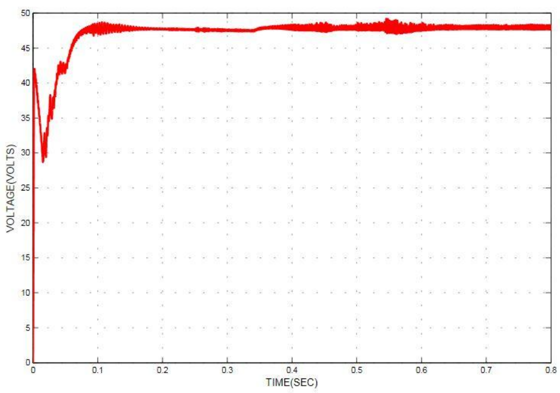

Fig.11. Bus Voltage of cascaded system with AACC and PI controller

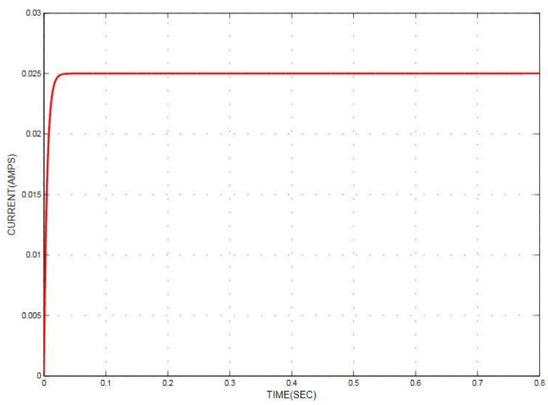

Fig.13. Io of cascaded-system with AACC and FUZZY controller

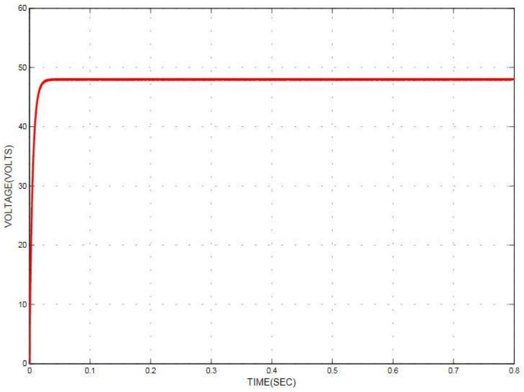

Fig.14. Vbus of cascaded-system with AACC and FUZZY controller

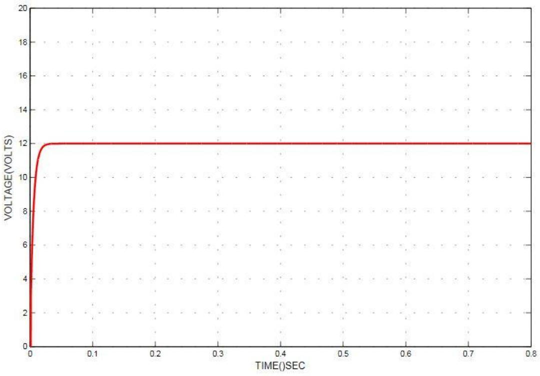

Fig.15. Vo of cascaded -system with AACC and FUZZY controller

CONCLUSION:

The instability problem in dc DPS can be easily solved by this new method which is most efficient method. It provides AACC as an equivalent adaptive bus condenser changed in accordance with cascaded system output power and mitigates impedance interaction in cascaded-system by mitigating the Zo of the sending end converter. Based on the stability margin of the cascaded-system, The AACC produces more energy to give large equivalent capacitor when the cascaded-system oscillations are high. And vice-versa happens when the oscillations are less. Oscillating voltage is within the allowable scope and AACC will be shut down when there is no oscillation. Hence the stability of the cascaded-system can be ensured with the use of AACC. And also no electrolytic condenser is required

TYPE	SETTLING TIME
with aacc	0.09
with aacc of fuzzy controller	0.02

The settling time of load current for AACC and FUZZY Logic controller is less when compares with cascaded system with AACC and PI controller.

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