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Adaptive Neuro Fuzzy Based Adaptive Droop Control In Multi-Terminal Hvdc For Wind Power Integration

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***Abstract**: The paper which proposes a hierarchical Adaptive Neuro Fuzzy Interface System (ANFIS) Predicated control framework intended for unpredictable peak voltage multi-terminal dc (MTDC) system. In this introduced ANFIS framework, essential command of multi-terminal dc network is localized and executes utilizing a general droop approach. The proposed ANFIS predicated auxiliary command is focused and manages the operating point (OP) of the system with the goal that optimal power flow (OPF) is accomplished. This work further elaborates through matlab simulations, on the correlative betwixt the essential and auxiliary controls. This comprises how essential controllers must be operated by auxiliary controllers so as to discover a continuous progress to ideal operating point. Time-domain simulations are organized to contrast the control technique designed with ordinary technique. This paper confirmed that the Adaptive Neuro Fuzzy strategy can enduringly follow effective demeanors of the converters.*

***Index Terms**: Adaptive Neuro Fuzzy Interface System (ANFIS), droop strategy, GSMMC, MTDC, offshore wind farm, WFMMC.*

I. INTRODUCTION

Multi Terminal high voltage dc (MTDC) has transpired as an efficacious resolution to merge offshore wind farms accompanying the onshore AC grids [1]-[2]. This can be successively advanced to the existent HVDC system with enriched power transfer resilience betwixt various offshore wind farms and onshore AC grids. As of recently, there are different topologies for the MTDC converters. Modular Multilevel Converter (MMC) emerges as prominent owing to its little switching losses, expandable and stableness. The fundamental test for MMC depended MTDC control is the DC voltage adjustment, it is crucial for the power stream and the potential equilibrium in the DC grid, homogeneous to the frequency in the AC grid. In the earlier examination Centralized control, decentralized control and the merging of two controls utilized [2]-[5]. An adaptive control methodology dependent on fuzzy logic. It is intended to alter the droop coefficient and accomplish ideal power allocation to little voltage fluctuations.[6]

In this paper, ANFIS is introduced to modify the droop coefficient and accomplish ideal power allocating with minuscule voltage change. Most significantly, effect of the droop coefficient on the complete steadiness of the MTDC network is examined by utilizing the eigen value examination and the time-domain simulation.

II. CONTROL OF MTDC WITH MMCs

A. Framework structure

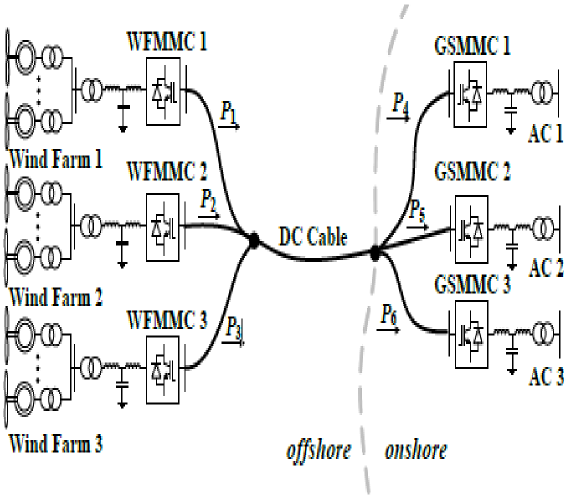

Fig: 1 Symbolic representation for integration of offshore wind forms and onshore ac grids

The system below work is represented in Figure.1 that is a symbolic six-terminal HVDC circuitry for offshore wind farms integration. It comprises the offshore wind farms, three wind farm side MMCs (WFMMCs), and three grid side MMCs (GSMMCs), on shore AC grids. This circuitry allows power transmission betwixt various MMCs. WFMMCs operates like power sources and GSMMCs operate like burdens. In this power transmission system, sources send all accessible power to grids.

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B. Control methodology

WFMMCs necessary to give ac power sources for the wind farms. Thus, the WFMMCs utilize the ac voltage and frequency management to maintain the voltage significance and frequency at point of common coupling (PCC) so as to make sure the most power infusion into the MTDC.

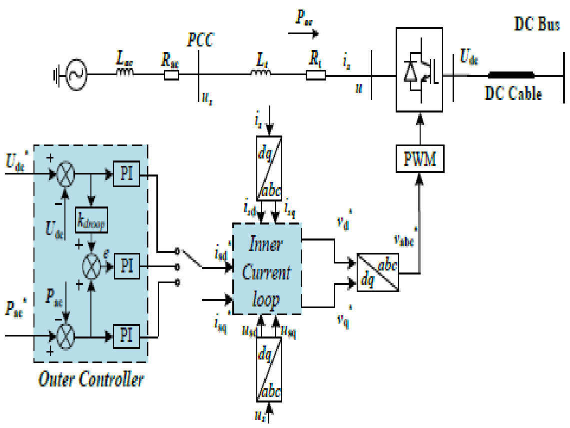

Fig:2 Symbolic representation of MMC controller

Figure 2 shows that modular multilevel converter control. It contains inner controller and outer controller. An outer controller used for governing the dc voltage and an inner-loop current controller for producing PWM signal. The droop control for ith GSMMCs is represented as

$$i^*_{sdi} = (k_{po} + \frac{k_{io}}{s})[(P^*_{aci} - P_{aci}) + k_{droopi}(U^*_{dci} - U_{dci})], i = 1,\cdots,k \quad (1)$$

Where K_{po}…… Proportional gain

K_{io}……..Integral gain

P_{aci}……ac power of the ith converter

U_{dci}……dc Voltage of the ith converter

U^*_{dci}…..Reference dc Voltage

P^*_{ac}...... power reference

K_{droop} ....droop coefficient.

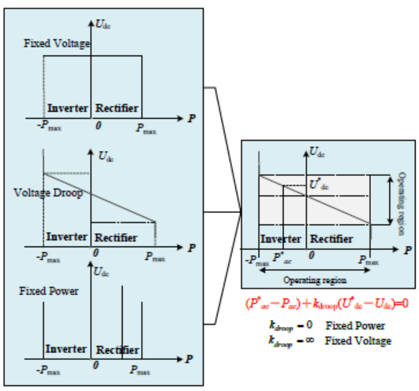

Fig:3 Voltage-power droop characteristics

Figure 3 indicates that if Kdroop is equal to zero, the droop control is deemed as the fixed power control. If Kdroop is equal to infinity, then considered as fixed voltage control. The converters performance is based on droop characteristics.

III. ADAPTIVE NEURO-FUZZY CONTROLLER ARCHITECTURE

Adaptive neuro fuzzy inference system (ANFIS) coordinates the top qualities in neural system and fuzzy system. This can possibly catch the advantages of two systems and it creates an advanced system. ANFIS is a kind of artificial neural systems based on the Takagi-sugeno fuzzy inference system (FIS). ANFIS use only one input and produce one output. Utilizing the stated informational index, a toolbox activity of ANFIS build a FIS where as the specifications of membership functions are balanced utilizing a back propagation algorithm. So as to have a thought of improved ANFIS design for advanced system, primary information is produced by PI regulator and that information is stored in workspace of MATLAB. Next type ANFIS editor in the main window of MATLAB after that ANFIS command window is opened. Next the information earlierly stored in workspace is stacked in ANFIS command window to make an improved ANFIS architecture. It is represented below.

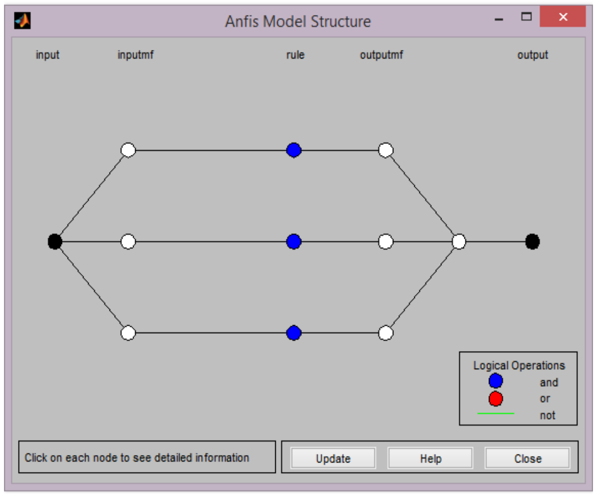

Fig:4 Advanced ANFIS design recommended by MATLAB/ANFIS editor

Figure.5. represent that the projected ANFIS based control design. Working of the hub components of each layer in the ANFIS configuration is explained below.

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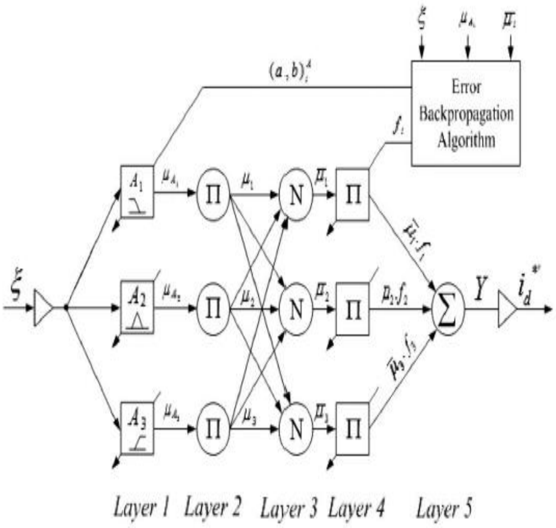

Fig:5 Block diagram of Anfis-based control design

The error betwixt reference dc voltage and actual dc voltage ($\xi=V_{dc}*-V_{dc}$) is supplied to neuro fuzzy controller and that error is utilized to adjust the resulting variables. The control of DC voltage supplies the i_d *.

***Layer-1*:** It is called as fuzzification layer. In this every hub is shown as a square. In this every input has 3 membership functions. Trapezoidal and triangular membership functions are utilized to diminish the calculation burden is appeared in Figure 6. The equivalent hub mathematical statements are represented as follows:

$$\mu_{A1}(\varepsilon)=\left.\begin{matrix} 1 & \varepsilon\le b_1 \\ \dfrac{\varepsilon-a_1}{b_1-a_1} & b_1<\varepsilon<a_1 \\ 0 & \varepsilon\ge a_1 \end{matrix}\right\} \quad (2)$$

$$\mu_{A2}=\left.\begin{matrix} 1-\dfrac{\varepsilon-a_1}{0.5b_2} & |\varepsilon-a_2|\le 0.5b_2 \\ 0 & |\varepsilon-a_2|\ge 0.5b_2 \end{matrix}\right\} \quad (3)$$

$$\mu_{A3}(\varepsilon)=\left.\begin{matrix} 0 & \varepsilon\le a_3 \\ \dfrac{\varepsilon-a_1}{b_1-a_1} & a_3<\varepsilon<b_3 \\ 1 & \varepsilon\ge b_3 \end{matrix}\right\} \quad (4)$$

The value of parameters (a_i, b_i) adjusted by using diffence in error. Then thus produces the values of every membership function. Here variables are mentioned as hypothesis variables or pre conditioned variables.

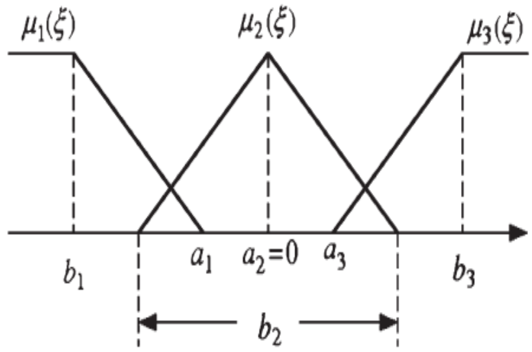

Fig:6 Three membership functions of Fuzzy

Layer-2: Here Each hub is represent as a circle and that circle is labeled as Π. Π is a symbol for multiplication. Output of first layer is given to the second layer as input. Here multiplication of input signals is takes place. Output of this layer is given to next layer.

$$\mu_i=\mu_{Ai}(\varepsilon_1).\mu_{Bi}(\varepsilon_2)\ .... \quad (5)$$

Where i=1, 2, 3, …

But in this project there is just a single input, so that this process is neglected. Output of layer-1 will straightforwardly go to layer-3.

***Layer-3*:** Here each hub is represent as a circle. Here compute the standardized power of each method as appeared as follows.

$$\overline{\mu_1}=\frac{\mu_i}{\mu_1+\mu_2+\mu_3} \quad (6)$$

***Layer-4*:** Each hub in this layer is a hub function

$$O_i=\overline{\mu_\iota}.f_i$$
$$O_i=\overline{\mu_\iota}\left(a_0^i+a_1^i\varepsilon\right) \quad (7)$$

where i=1, 2, 3….

Variables a_0^i, a_1^i are adjusted as the role of input (ξ). Variables in this layer are represented as subsequent variables.

***Layer-5*:** It is the output layer. The output from this layer is multiplied with the standardizing component to acquire the effective power current constituent.

III. SIMULATION RESULTS

Framework setup and parameters appeared in Figure.7 and Table, the framework layout is setup in MATLAB. Effective reaction of the framework with fixed droop coefficient and the adaptive droop coefficient following the converter failure is examined by the time-domain simulations. The simulations are likewise used to approve the steadiness results.

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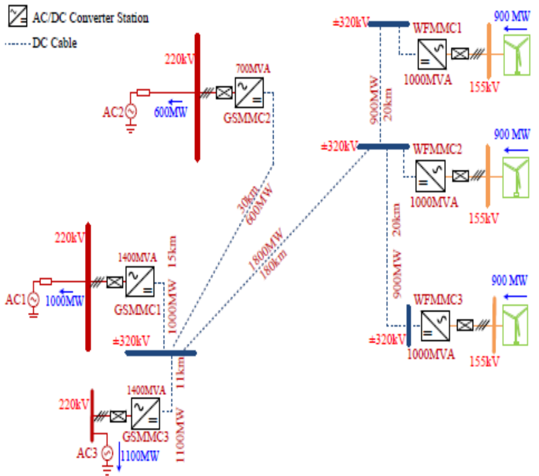
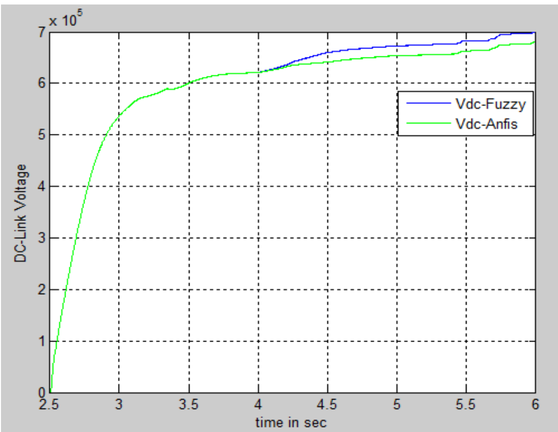


Fig:7 Layout of the six-terminal HVDC network

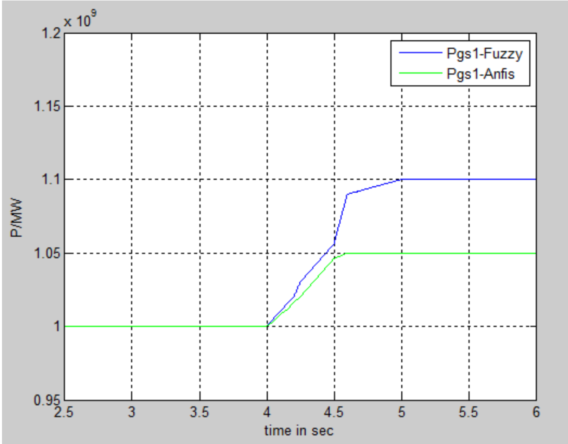
PARAMETERS OF MMC-MTDC SYSTEM

Para.	WFM MC1	WFM MC2	WFM MC3	GSM MC1	GSM MC2	GSM MC3
AC rated voltage/kV	155	155	155	220	220	220
Transformer/MVA	1000	1000	1000	1200	1000	1200
DC rated voltage/kV	640	640	640	640	640	640
Converter/MVA	1000	1000	1000	1400	700	1400
DC voltage U_{dcref}/kV	—	—	—	640	640	640
Power P_{ref}/MW	—	—	—	1000	600	—
AC voltage U_{sref}/kV	155	155	155	—	—	—

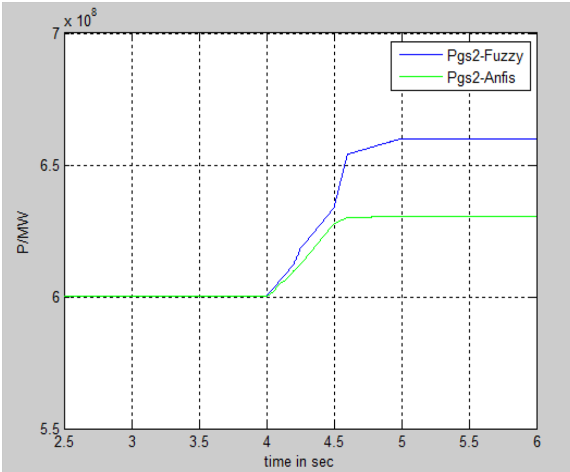
GSMMC3 failure:



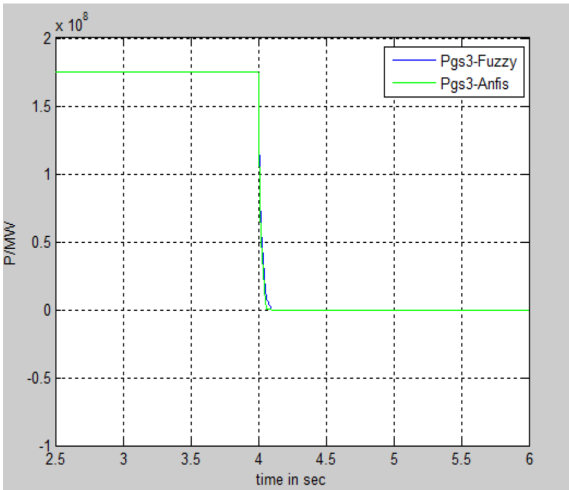
(a) DC-link Voltage



(b) Output power for GSMMC1



(c) Output power for GSMMC2



(d) Output power for GSMMC3

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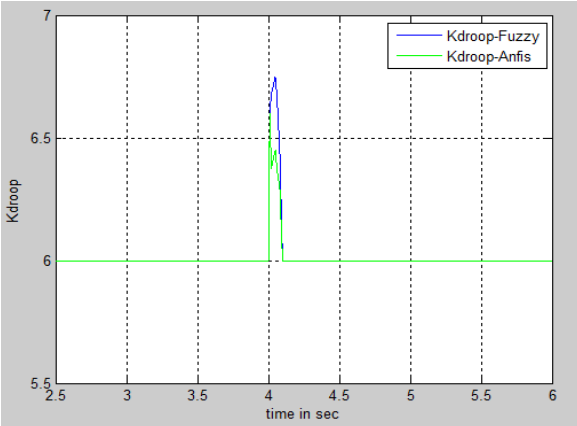

(e) Kdroop curves for fuzzy and ANFIS

Fig:8 Simulation results when GSMMC3 failure

At 4s because of failure of $GSMMC_3$, the power is decreased to zero. $GSMMC_1$ and $GSMMC_2$ remunerate the power insufficiency and the power mention esteems are 1000MW and 600MW, individually. While the WSMMCs output power is 1800MW. Transferring power is higher than that the getting power, leading about increasing in DC voltage.
It tends to be optically discerned in Figure.8 (a), the dc voltage achieves the consistent value 653kV by the adaptive droop coefficient contrasted with 658kV by the fine-tuned one. It is conspicuous that there is more immensely colossal difference in dc voltage when a fine-tuned droop control is utilized while the proposed system engenders a lot more tightly voltage control. In integration, in the intensity alteration scope of $GSMMC_1$ and $GSMMC_2$, the dc voltage variation can be diminished with higher voltage control precision. In Figure.8(b) and (c), because of the puissance edge of $GSMMC_1$ is more sizably voluminous than that of $GSMMC_2$, contrasted with the regular control system, $GSMMC_1$ will postulate more power so that $GSMMC_2$ with more minute power edge shares less potency. The output power for $GSMMC_3$ decreased to zero in Figure 8 (d) for blackout. Figure.8 (e) exhibits droop coefficient deviation curves of Fuzzy interface system and ANFIS. Hence $GSMMC_1$ has more sizably voluminous power edge. Droop coefficient extends in addition to dc voltage variation incrementing at the starting failure moment. Accompanying the transferred power of $GSMMC_1$ elevating puissance edge scope enhances limited. Droop coefficient is regulating aback to around 6.0 with the avail of ANFIS system.

V. CONCLUSION

Here the work demonstrates a pecking order ANFIS design for HVDC network. The ANFIS predicated auxiliary control is considered as a centralized controller that operates as an ecumenical activity analyzer. Predicated on voltage, power and droop coefficient quantifications arising out of the whole system, auxiliary command again calculate the OPs of essential control in an endeavor to limit a pre defined target work. The proposed method is examined in MATLAB with a six terminal HVDC circuitry utilized in literature for droop coefficient analogy. Replications of framework are just essential management is effective and with both, essential and auxiliary controllers performing along are distinguished. It is presented that congruous measuring the voltage of the system stays in the equivalent working margins even for astronomically immense burden transients. In the examined situation decrease the transmission losses of 25% was descried betwixt essential and auxiliary controllers.

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