

Analysis of Hybrid Power Systems with Fuzzy Controller to the Reactive Power Management

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ABSTRACT

Standalone hybrid systems are need of the hour in electrical power sector. The reactive power support is most vital issue in the voltage point of view. Wind energy has received the special attention of researchers in recent times. Attempts to generate electricity from wind energy have been made since the end of nineteenth century. A single renewable energy source may not be able to meet the load demands apart from the fact that continuous supply of energy may not be ensured. Here comes the importance of Hybrid energy systems such as Wind-diesel, Wind-PV. Advanced FACTS technologies have utilized for reactive power support to the system. The fuzzy logic has implemented in the control circuit of STATCOM, which is relatively advantageous compared to conventional PI controller. The control strategy is verified through model simulation study whose results conform the significance of the control methodology incorporated in the paper.

I.INTRODUCTION

Ever growing electric power demand by infinite consumers all around the world pushes for reforms in power sector. One of the most lucrative ways to meet this surplus demand is by encouraging of non-conventional energy sources and development of hybrid power systems to cater the needs of a bunch of consumers. If the renewable energy sources are sole power sources and not connected to the grid, they can be termed as standalone or isolated hybrid systems. If the renewable energy systems are connected to the grid directly, then they are called grid connected systems. This type of generation is called distributed generation or embedded generation. Ideally, diesel generator coupled with solar or wind form a hybrid energy system. Sometimes, the diesel systems are coupled with synchronous generators which are used to meet the needs of remote areas which are not accessible to power. Induction generators are also an alternate option which can link up with the diesel system to produce power in an isolated mode of operation of the power system. But the problem with induction generators is that regulation of voltage is not very satisfactory and also it requires exciting current which significantly affects the output power and PF1.

An alternative solution to this problem is PMIG. The rotor of the induction machine is embodied with permanent magnets, hence the name permanent magnet induction machine. Numerous models have been

prescribed in literature regarding the modeling of PMIG such as d-q axis model, per unit model; etc. The main objective is that there should not be any power imbalance between the source and the load which would otherwise cause severe disturbances in the power system. This calls for dynamic reactive power compensation according the changing system conditions. Advanced FACTS technology based devices are readily available which makes the job of reactive power supplement very easy. Voltage Source Converter (VSC) is the type of power supplement which is capable of KW as well as KVAR supply. STATCOM2 is chosen for the reactive power requirement.

II.MATHEMATICAL MODELING

The mathematical model of standalone hybrid energy system with STATCOM as depicted in Figure 1. The P and Q of the Wind-Diesel system under steady-state conditions are as shown.

$$P_{PMIG} + P_{SG} = P_L$$

$$Q_{SG} + Q_{com} + Q_{PMIG/IG} = Q_L$$

Simultaneously, loads associated with the system will be subjected to fluctuations due to this change because of the system voltage-load characteristics as given below

$$D_V = \frac{\partial Q_L}{\partial V}$$

The total loads in exponential representation is given by

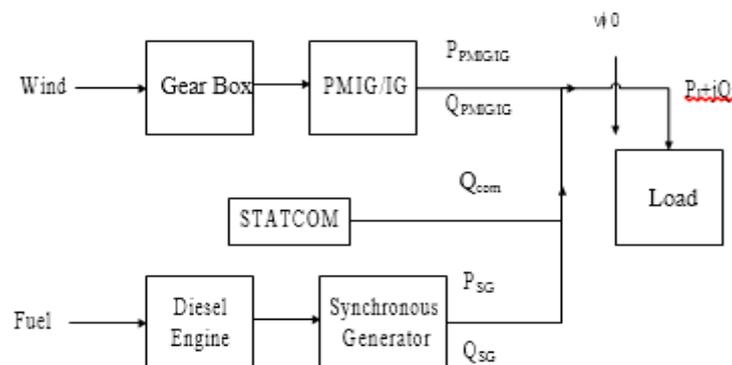


Figure 1: Standalone hybrid system considered in this paper

$$Q_L = c_1 V^q$$

$$D_V = \frac{\Delta Q_L}{\Delta V} = q \cdot \frac{Q_L^0}{V^0}$$

A standard IEEE type-1 excitation system is chosen to model the SG while neglecting the effect of saturation effect (S) which is represented in Figure 2.The equations related the excitation system are given

as

$$\Delta E_{fd}(s) = \frac{1}{K_E + sT_E} \Delta V_a(s)$$

$$\Delta V_f(s) = \frac{K_F}{T_F} \cdot \frac{1}{1 + sT_F} \Delta E_{fd}(s)$$

$$\Delta E'_q(s) = \frac{1}{(1 + sT_G)} [K_1 \Delta E_{fd}(s) + K_2 \Delta V(s)]$$

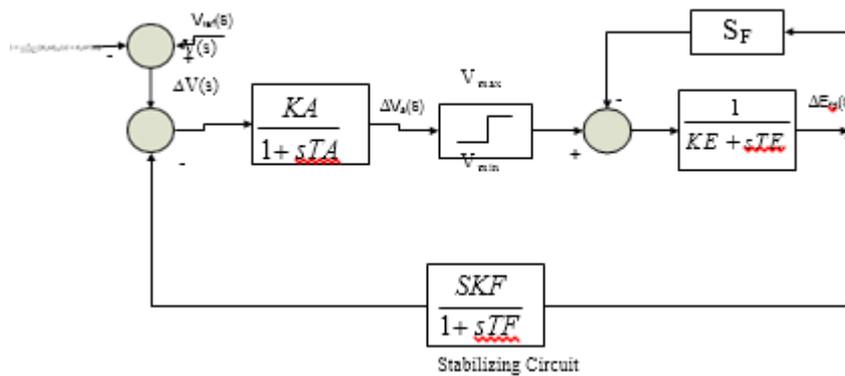


Figure 2: IEEE type-I excitation system

The STATCOM is electrically equivalent to voltage source in synchronous mode which produces voltages without any unbalancing and equipped with fast control strategies STATCOM typically which includes dc capacitor and coupling transformer and reactive power control accomplished by STATCOM4 is given in Figure 3. The real power injection is given by

$$Q_{com} = kV_{dc}^2 B - kV_{dc}VB \cos(\alpha - \delta) + kV_{dc}VG \sin(\alpha - \delta)$$

The kV_{dc} term in the equation is constant/steady state component including voltage across the capacitor.

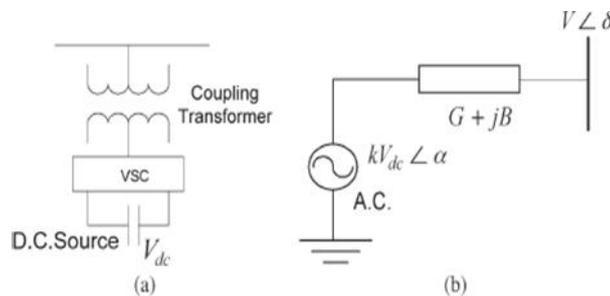


Figure 3: (a) STATCOM (b) STATCOM model

III. WIND-PV SYSTEM

The system is modified by placing PV in place of diesel based energy source. Also the PI control employed in the control circuit of STATCOM is replaced with Fuzzy logic controller. The PV6 system is appropriately modeled and suitably incorporated in the small signal analysis. The figures depict the performance of the system with the modified model. The controller using Fuzzy logic resembles the logic belonging to mankind. Fuzzy Logic control is more advantageous than PI and PID controllers because controller is more Flexible when compared with other types of controllers. Unlike PI controllers these controller has multiple inputs and multiple outputs. The process involves creating of membership values after choosing proper membership function.

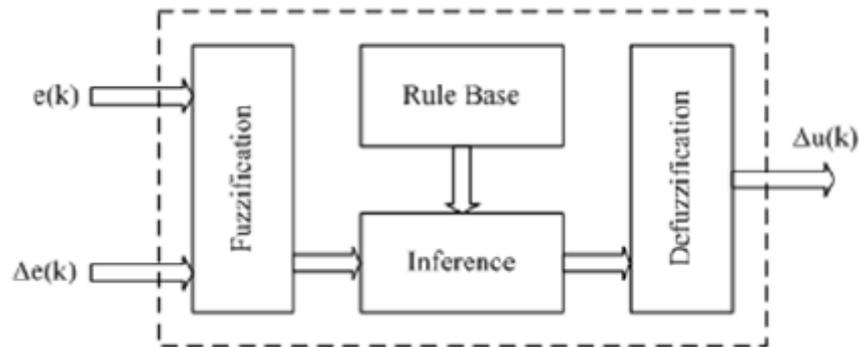


Figure 4: Fuzzy logic controller

IV. SOLAR PANEL MODELING EQUATIONS:

From Solar equivalent circuit,

$$I = V_o/s/R1$$

$$\frac{V_o}{I} = sR1$$

Boost converter equations

$$V_o(s) = L \frac{di}{dt} + iR$$

$$\frac{V_o}{s} = LSI + IR$$

$$\frac{V_o}{V_{o1/R}} = S(LS + R)$$

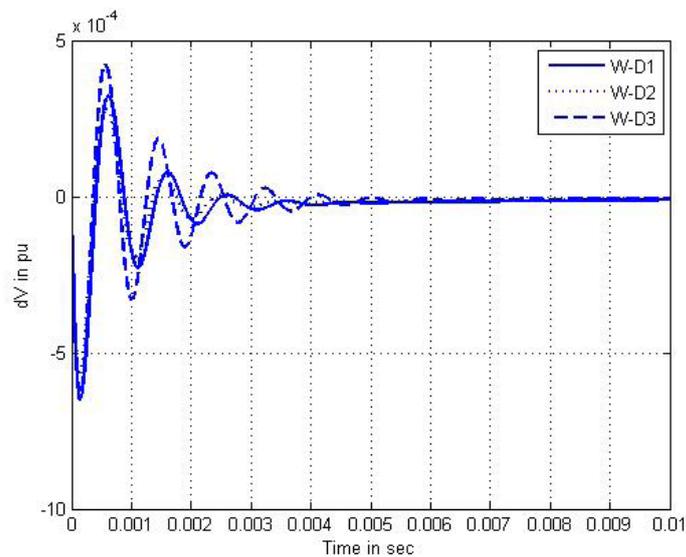
$$\frac{V_o'}{V_o} = \frac{1}{S(L/Rs+1)} \frac{V_o'}{V_o} = \frac{1}{S(L/Rs+1)}$$

So that by solving above equations, we get

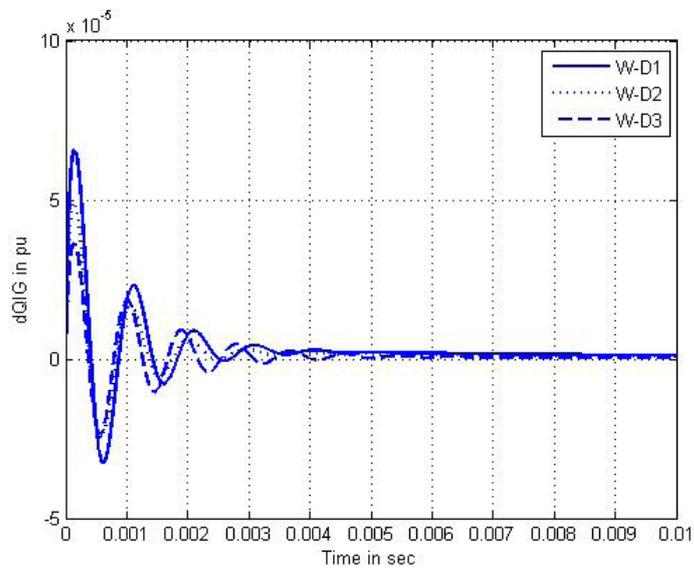
$$\frac{V_{O1}}{I} = \frac{R_1}{(L/RS + 1)} = \frac{R_1}{(\tau S + 1)}$$

V.PROPOSED SYSTEM TRANSIENT PERFORMANCE:

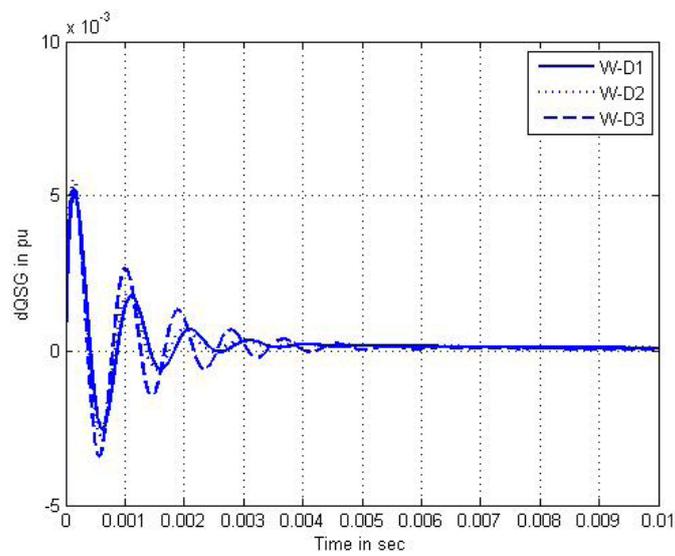
The simulation results of hybrid system configurations are shown in figures. The ideal gain numerical of the STATCOM using the standard criterion is given in figures. It is found that the gain constant would be larger if the STATCOM rating is less or the deviation between the output and demand is more. Figure 5 depicts the case for step increase of 1% in the load and with no alteration of input power of wind system. The wind turbine size increases with IG increases with the increment of the voltage deviation at peak value. The increment in the load is supplemented by the compensator installed in the system.



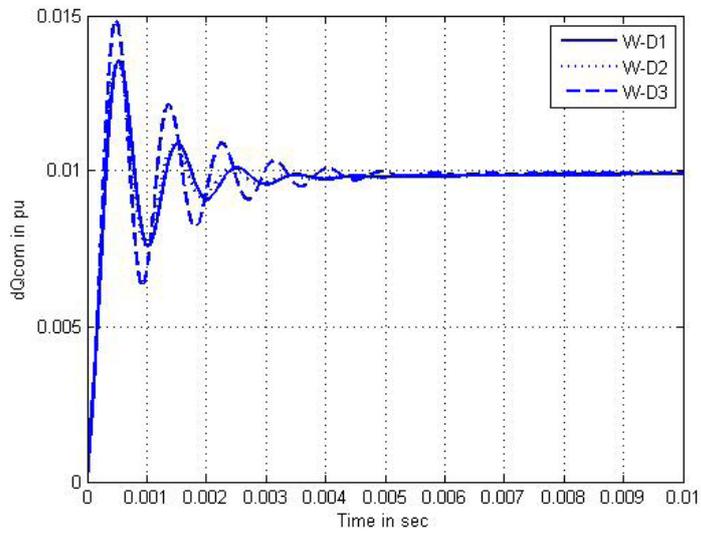
(a)



(b)

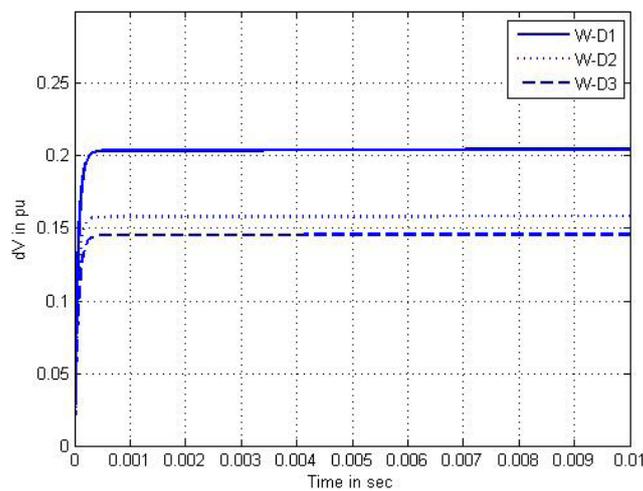


(c)

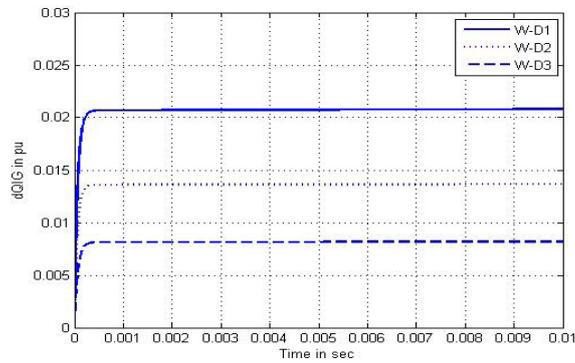


(d)

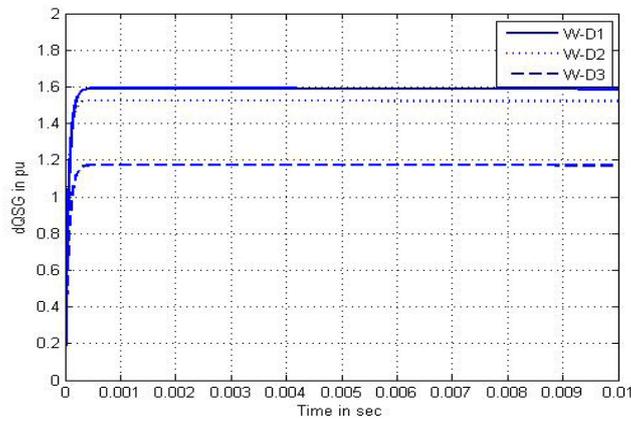
Figure 5. Dynamic response of the proposed system configurations with IG under transient conditions with 1% increase in load. (a) Voltage change vs. time (b) Reactive power change of IG vs. time (c) SG Reactive power change vs. time (d) STATCOM reactive power change vs. time.



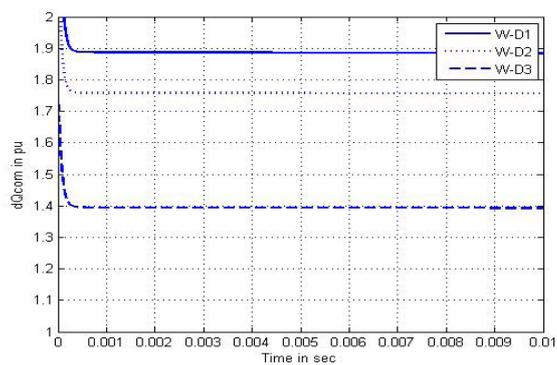
(a)



(b)



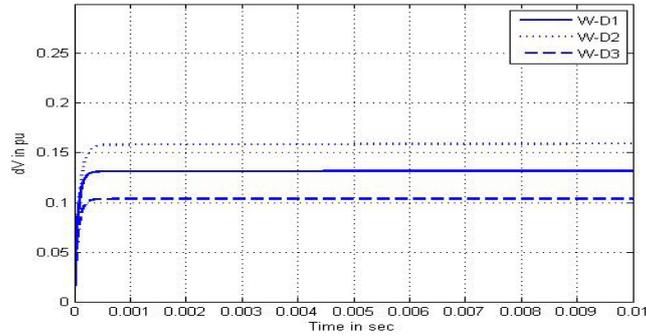
(c)



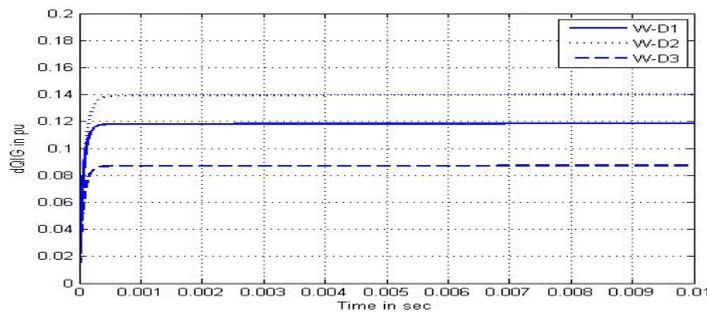
(d)

Figure 6. Transient responses of the system with 1% load increment. (a) Change in voltage vs. time (b) Change in reactive power of IG vs. time (c) Change in reactive power of SG vs. time (d) Change in reactive power of STATCOM vs. time.

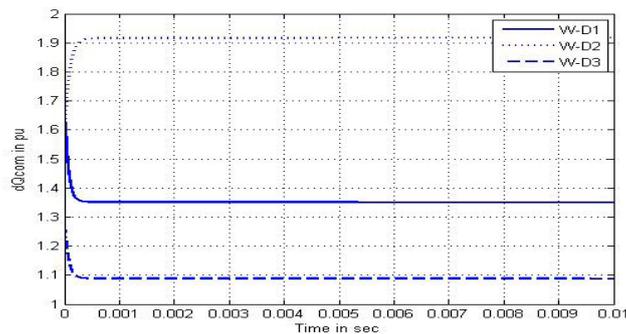
Figure 6 shows the responses of Wind-PV system for an increase of 1% in load. When comparing with Wind-Diesel system with IG the settling time decreases from 0.007sec to 0.001sec, Also the deviations are reduced when compared with the Wind-Diesel System.



(a)



(b)



(c)

Figure 7. Transient response of the system with PMIG for each 1% increase in Load and input wind. (a) Change in voltage vs. time (b) SGs change in reactive power vs. time (c) Change in reactive power of STATCOM vs. time.

Figure 7 shows the response of the Wind and Photovoltaic system using PMIG for 1% load increment and 1% step increase in input power of wind system. When comparing with Wind-Diesel system with PMIG the settling time decreases from 0.006sec to 0.001sec, also the deviations are reduced when compared with the Wind-Diesel System.

VI.CONCLUSION

The reactive power control strategies for various system configurations with PMIG and IG are evaluated in the simulation study. It is observed that interconnected hybrid systems are effective solution to meet the remote and inaccessible load demand. The compensator used for reactive power support is STATCOM. The configuration of the hybrid system is changed from wind-diesel to wind-PV and performance evaluation is carried in small signal analysis mode. The controller employed in control circuit of the STATCOM is changed from Proportional Integral (PI) based control to Fuzzy logic based control. It is found out that by using fuzzy controller the settling time decreases and also the peak over shoot decreases which is advantageous than PI control. Also by including the saturation function the settling time and also the peak over shoot decreases when compared with saturation function neglected.

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