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Fuzzy self tuning PI controller based inverter control for voltage regulation in off-grid hybrid power system

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Abstract

The management of reactive power has become an important aspect of the off-grid power system as voltage control is a key parameter in the quality of supply. This paper presents voltage profile control through VAR support by PV inverter in off-grid hybrid power system . PV (Photovoltaic system) inverter when oversized its reactive power capacity increases while injecting full active power and can provide necessary reactive power support to the system to maintain the voltage profile flat. The system considered for study consists of wind power generation by Induction Generator, Photovoltaic system with inverter and Synchronous Generator based diesel engine. The intelligent control based on Fuzzy with classical PI control strategy is presented in this paper to control reactive power of PV inverter to regulate load bus voltage and system model with developed intelligent control is simulated in SIMULINK/MATLAB, under the step load change and step change in input wind power and the results, obtained separately from PI controller and proposed Fuzzy self tuned PI controller are compared to validate the advantages of the proposed intelligent control algorithm.

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Keywords: Reactive power ; Voltage control ; Fuzzy control ; Inverter.

Nomenclature

FST	Fuzzy logic control based Self tuning
ITAE	Integral time absolute error.
V, ΔV,	Load bus voltage and change in load bus voltage due to disturbances

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Q_{IN} ,Q_{SG},Q_{IG} ,Q_L,Q_{CP}	Inverter ,synchronous generator, induction generator load &capacitor reactive power,
PL ,P_{WD}	Real power demand of Load and wind power input to Induction generator
X_{Sd}, X_{Sd}'	steady state and transient of synchronous generator.
Re, xe, x_m, s	equivalent resistance ,reactance, magnetising reactance and slip of Induction generator
r_1,x_1,r_1',x_2'	stator resistance & reactance,rotor resistance & rotor reactance referred to stator of IG
k_{VQ},T_{VQ}	gain and time constant of off-grid hybrid power system

1. Introduction

There is growing need of developing as well as implementing cost effective energy solutions , to meet energy demands and also minimize potential environmental impacts for areas which are remote wherein the extension of public grid is challenging and difficult. Hybrid power systems based on wind, PV, Biomass, etc. are very promising solutions with excellent prospects in an efficient and sustainable way to cater the local demands of remote locations [1]. The abundant amount of wind energy and solar energy is observed in the remote areas, provides an opportunity to use renewable sources for power generation.[2] The issue with renewable sources is that they are not predictable and moreover fluctuating in nature, to achieve reliable and quality supply needs an appropriate control mechanism to maintain voltage and frequency within specified limits

The Off-grid hybrid power system (OFHPS)considered in this work consists of Diesel generator(DG), Wind generator, and Photovoltaic generator(PV). This type of OFHPS has been already in existence in several small islands or isolated communities [3], The system reactive power requirement varies with reactive power demand of load and also Induction generator connected to wind turbine consumes reactive power. The reactive power imbalance in the system causes unsatisfactory voltage regulation characteristic, system voltage variation may go beyond the voltage allowable bounds and the quality of power supply will not be tolerable for end users. The previous works on the voltage control scheme of HPS using Static voltage Compensator and Static synchronous compensator) for reactive power is reported in [4-6].The paper [7] has discussed the potential of distributed generation systems equipped with an appropriate power electronic interface to support reactive power other than the supply of active power to the utility. A promising answer to the voltage regulation problem in off-grid HPS is to utilize PV inverter capability to generate or consume reactive power to control voltage . Classical PID and PI controllers are commonly used to control inverter. The PI controller with fixed gains constants performs well for rated operating condition, but fails to provide better response under variable operating condition. [8].Therefore control structures needs the flexible controller with adjustable nature to cope up with the effects of system parameters variations..

Fuzzy Logic Control(FLC) is demonstrated its strength as it is capable to work over wide range of operating conditions and its simple to modify fuzzy rules, which mimic a human operator's strategies., FLC rules are represented in linguistic terms of natural language.[9,10]. Hence this paper present the intelligent control based on combination of fuzzy logic with classical PI controller to control VAR power of inverter for voltage profile stability while PV inverter supplying active power to the system.

1. System configurations and mathematical model

The block diagram of configuration of the system considered in this study is as shown in Fig. 1. System consist of SG (Diesel Generator) with excitation control, variable wind speed turbine with IG, PV system with DC-AC inverter, and a capacitor bank are connected to a common bus. The total load is lumped as single load is connected to common bus .

At steady state operating condition, the system reactive power equation is balanced, is given as

$$Q_{SG} + Q_{IN} + Q_{CP} - Q_L - Q_{IG} = 0 \quad (1)$$

When there is a small change in load ΔQL , around steady state condition, then system voltage deviates and hence reactive power demand of various components of the system under study changes. The net reactive