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Power Flow Control in Hybrid Power System Using Modern Control Technique

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Abstract*: -- The main aim of this paper is to make the combination of grid interfacing inverters and 3-phase 4-wired linear/non-linear unbalanced loads at the point of coupling to appear as a balanced linear load to the grid. This new control concept is demonstrated with extensive Fuzzy based logic studies. The structure of the designed controller consists of outer power with harmonic control loop, middle voltage control loop and inner current control power loop for real and reactive power control in dq reference frame. The developed controller controls the real and reactive power supplied by the DG (Distributed Generation) at the PCC (Power Controlled Converter). The controller is designed to deliver current at unity power factor at PCC. An increase in reactive power demand and harmonics at PCC due to change of load and grid impedance variation would affect the system voltage at PCC. A five-level inverter is used as a shunt active power filter (APF), taking advantages of the multilevel inverter such as low harmonic distortion and reduced switching losses. It is used to compensate reactive power and eliminate harmonics drawn from a thyristor rectifier feeding an inductive load (RL) under distorted voltage conditions. The APF control strategy is based on the use of self-tuning filters (STF) for reference current generation and a fuzzy logic current controller. The use of STF instead of classical extraction filters allows extracting directly the voltage and current fundamental components in the α-β axis without phase locked loop (PLL). The MATLAB fuzzy logic toolbox is used for implementing the fuzzy logic control algorithm.

***Keywords* — Linear Load, Non-Linear Load, Fuzzy Logic, Converters, Filters, Power Flow, Grid system.**

I. INTRODUCTION

This paper is to control power flow of over lines to enhance the system, capacity, alleviate overloads, and improve the reliability. DSRs are used to balance flows in the phases of an unbalanced line, and to control the distribution of flow in parallel paths and it also addresses the problem of frequency regulation in an AC micro-grid due to sudden load or powerfluctuations. A fuzzy gain scheduled PID (FGSPID)controller is proposed. The results of FGSPID controller are compared to those obtained with conventional PIDcontroller. Simulated results show that the FGSPID controller provides improved dynamic performance than fixed gain conventional PID controller.

The generated power from the wind turbines and PV cells are directly affected by changing in environmental conditions. Frequency regulation in AC micro grid occurs due to sudden changes in load or power fluctuations PV interfaced inverters with tap changing transformer is used for voltage control. The performance of voltage control is affected due to forecast error. In Distribution Networks (DNs) analysis reactive/active power regulation is used for maintaining voltage regulation. The steepest decent method is used to extract the disturbance of current fluctuation. Hysteresis controller is used for minimizing the total distortion. When load changes occur in both conductance and admittance the voltage is regulated and tuned. D-STATCOM control method is used to alleviate voltage fluctuations in high level penetration of distributed power generation systems. Multi Period AC Optimal power flow is used to solve the economic dispatch problem such as minimizing the total energy losses.

II. PROPOSED SYSTEM CONFIGURATION AND DESCRIPTION

The configuration of the proposed AC micro-grid system is as shown in Fig. 2 and consists of hybrid power generation along with battery energy storage subsystems comprise WTGs, PV, FCs, DEG, whereas, the energy storage subsystems is a BESS connected to the load side. Only the PV and FC require suitable power converters for exchanging energy with the AC microgrid system under study. The DEG is the subsystem which is system under control and participates in frequency regulation by delivering excess power to the system when the total power generated by the WTG, PV, and FC is insufficient. DEG lowers its output in the event of surplus power generation by the WTG, PV, and FC. The net power generation (Ps) is the sum total of the output power of WTG (PWTG), output power of DC-AC converter connected to FC (PFC), PV (PPV and output power of DEG (PDEG).

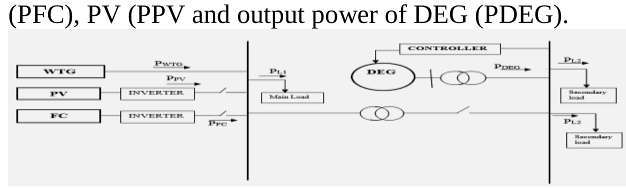


Fig.1: Single-line diagram of the proposed Hybrid power system with AC micro-grid

Nominal values of the DG units as well as loads, as used in this study, are given in Table I. The AC micro-grid system nominal frequency is considered as 50 Hz.

Table. I: RATED POWER OF DG UNITS AND LOADS

Rated power(KW)		**Load(KW)**	
WTG	155	$P_{L\ main}$	300
PV Panel	40	P_{L1}	30
FC	40	P_{L2}	30
DEG	100		

III. CONTROLLER DESIGN

A. Conventional Controller

PID controller, regarded as the standard control structure of the classical control theory, is a generic control loop feedback mechanism widely used in industrial control systems. The performance specification of the system depends on the values of proportional, integral, and derivative gains Kp, Ki, and Kd respectively. The tuning of these gain values will cause variation in observed response. The controller output u(t) in terms of error e(t) can be mathematically expressed as

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt}$$

This equation can be written as

$$u(t) = K_p \left(e(t) + \frac{1}{T_i} \int e(t)dt + T_d \frac{de(t)}{dt} \right)$$

where, Ti, and Td are integral and derivative time constants.

The PID controller is implemented for the control of DEG unit of the AC micro-grid of Fig. 1 for frequency regulation and the heuristically optimized gain parameters of the controller.

B. Proposed Fuzzy Gain Scheduled PID Controller

The proposed fuzzy gain schedule PID controller is a PID controller that employs the Fuzzy Inference System to optimally tune the gain parameters , and according to error e(t) and rate of change of error de(t)/dt. The control structure of the proposed controller is as depicted in Fig. 2. In this scheme, there is hybrid use of conventional control and fuzzy computing. The gains of the controller are stored in a fuzzy rule base beforehand and the fuzzy system provides suitable values for the controller gains depending upon the dynamic operating conditions.

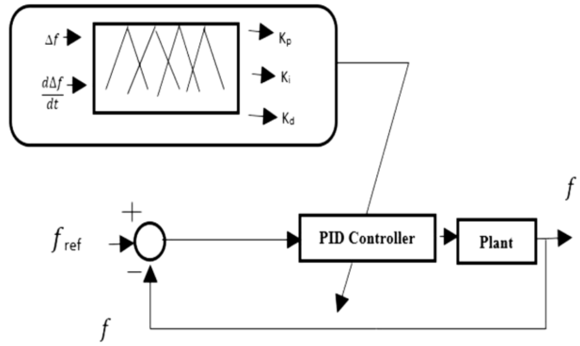
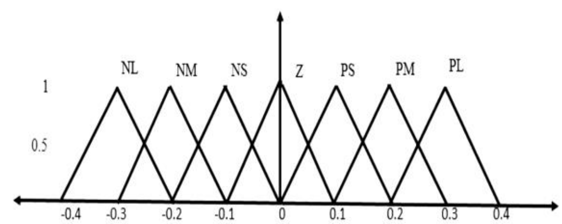
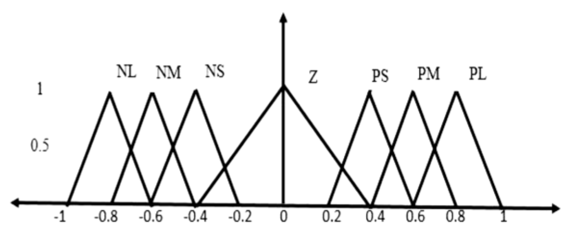


Fig. 2: Control structure of Proposed FGSPID

The suitable fuzzy rules for the FGSPID are designed which are given in table III. These fuzzy rules are simple and have been developed keeping in view the practicalaspects of system operation. The fuzzy inference system, used here is Mamdani type where, the frequency error (Δf) and the rate of change of frequency error (d/dt of (Δf)) act as the two inputs and the gains, and are the outputs. The triangular membership functions of the seven linguistic terms for each of the two inputs are as shown in Fig.3, where NL, NM, NS, Z, PS, PM and PL represent negative large, negative medium, negative small, zero, positive small, positive medium and positive large respectively.



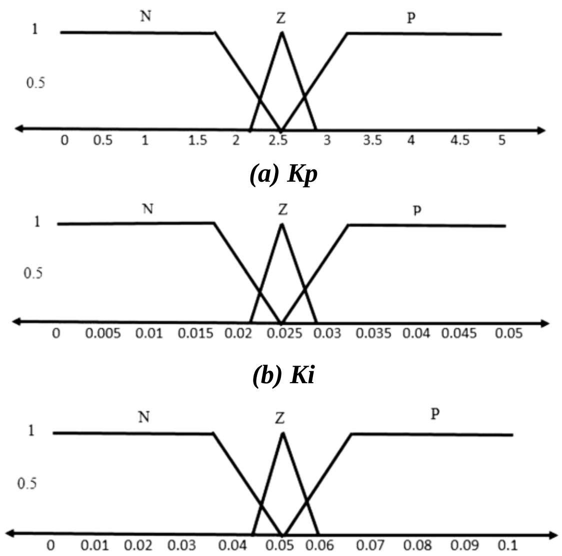
(a) Error(Δf)



(b) Rate of change of error (d/dt of (Δf))

Fig. 3: Membership functions of e(t) and d/dt of e(t)

The membership functions of the three linguistic terms for each of the three outputs Kp, Ki and Kd and are as shown in Fig. 4, where N, Z and P represent negative, zero and positive respectively.



(a) Kp

(b) Ki

(c) Kd

Fig. 4: Membership functions of Kp, Ki and Kd

IV. RESULTS AND DISCUSSION

To demonstrate the effectiveness of the proposed intelligent control scheme, time-domain simulations are performed in the Simulink using Sim-Power block sets of MATLAB software. Time-domain simulations under various operating conditions are carried out. The three cases; i) solar irradiation variations, ii) wind speed variations and, iii) Load variations are considered for investigating the performance of the controllers implemented. The total power (Ps) absorbed by the connected main load is300 KW under normal operating condition i.e. with solar irradiation of 800 W/m2 and wind speed of 12m/sec. Output power variations of PV and wind power systems at different duration of time are shown in Fig. 5 (a, b). The load demand variations are as shown in Fig.5 (c). Simulation results under various operating conditions are, respectively, analyzed in the following subsections.

A. Solar irradiation variation

- Solar irradiation assumed during 0s < t < 4s of 600W/m2.
- Solar irradiation assumed during 4s < t < 6.5s of 1000 W/m2, Because of this the frequency rises as total power generated becomes greater than total power demand due to the increased output power of the PV system.
- Solar irradiation assumed during 6.5s < t < 17s of 800 W/m2. Because of this the frequency drops as total power generated becomes less than total power demand due to the decreased output power of the PV system.

Corresponding variation in PV system power is as shown in Fig. 5(a).

B. Wind speed variation

- For 0s < t < 8.5s, wind speed, VW is 12 m/s.
- For 10.5s < t < 17s, wind speed, VW is 14 m/s. Because of this the frequency rises as total power generated becomes greater than total power demand due to the increased output power of the wind power system.

Corresponding variation in wind power is as shown in Fig.5(b).

C. Load variation

- For 0s < t < 12.5s, connected load is 300 KW.
- Sudden load inject: At 12.5s a load of 30 KW is injected to the system, because of which frequency drops as total power demand is greater than total power generated.
- Sudden load removed of 30 KW at 15 sec, because of which frequency rises as total power demand becomes less than total power generated.

Corresponding variation in load is as shown in Fig. 5 (c).

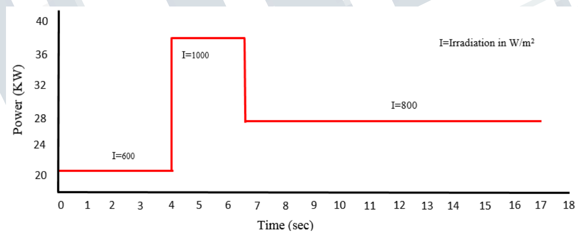


Fig. 5(a): PV power variation with irradiation at different time

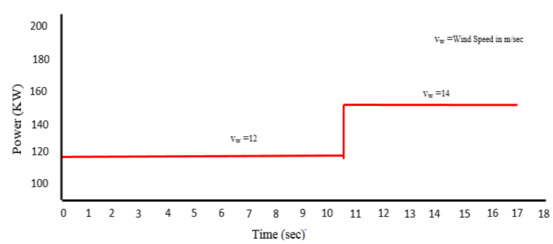


Fig. 5(b): Wind power variation with wind speed at different time

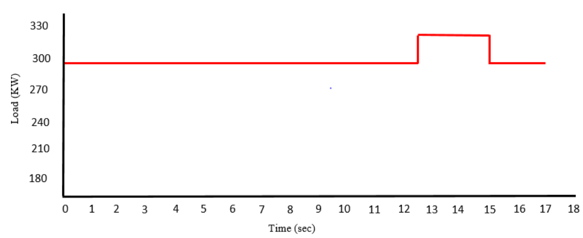


Fig.5(c): Load variation with time

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V.CONCLUSIONS

The performance of the AC micro-grid system with respect to the frequency regulation is investigated under the three cases of disturbances as discussed above. A better performance of the proposed intelligent FGSPID controller is clearly visible from system frequency response, when the micro-grid system is subjected to disturbances due to variation in solar irradiation, the wind speed variation and the load change at different intervals of time. Fo large disturbance due to wind power variations, the peak deviation with FGSPID controller is relatively large, though. However, the proposed controller is able to eliminate the system frequency deviations due to all the three disturbances more quickly than the conventional PID controller and also the response is less oscillatory and settles faster in case on FGSPID. The results may be further improved by fine tuning of the fuzzy rule base.

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