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Frequency Control Method by Integration of PVs and EVs in Power industry

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Abstract: In this paper, a frequency control method by integration of (PV) photovoltaic generation and (EV) Electric Vehicles is studied, the proposed method is compared with conventional technique based frequency control method. Simulation results shows that the proposed method is more reliable to reduce the deviation in frequency and tie-line power.Photo-Voltaic cells (PV) and Electric Vehicles (EVs) have many advantages for reliable and stable power supply. When connected to the grid, EV battery can behave as mobile energy storage making EV capable of either charging via grid-to-vehicle (G2V) as a "load" or discharging via vehicle-to-grid (V2G) or vehicle-to-building (V2B) as a "generator" or a dispatchable "back-up storage". This bi-directional power flow feature provides flexibility needed to match variability of the renewable sources.
Keywords: Fuzzy Control, PV, EV,V2G.

I.INTRODUCTION

The Load Frequency Control (LFC) is used to control the frequency deviation and maintains the dynamic performance of the system. In a Photovoltaic (PV) power generation systems, power output is not constant and fluctuates depending upon weather conditions. This fluctuating generated power causes frequency deviations in the system and reduces the reliability of the isolated power utility or micro-grid when large output power from several PV systems is penetrated in the utility. In this work, to overcome the above problems, a three area hydro-thermal power plant combined with PV systems and electric vehicles (EVs) is used. And the system is controlled with intelligent fuzzy based technique. The frequency control strategy method is used for levelling the fluctuations of combined power output from multiple PV systems and electric vehicles (EVs) used with. This frequency control method is proposed from the view point of the frequency fluctuation problem produced by the large penetration of PV power and sudden load variation.

Proportional integral derivative (PID) controller is still the most common controller in power industries, because of its reliability and stability and to tune less number of parameters. But, it is recommended for the control of process of low to medium order. To determine the optimal value of PID Controller parameters through conventional tuning method is difficult. The performanceof the controller can be further improved by proper setting of its gains. Many soft computing techniques have been employed to enhance the performance of controller to get optimal results, In this present work conventional controller like PI, PID and also intelligent controller like fuzzy logic controller to optimize the power system frequency and tie-line power in interconnected power system along with smart grid (PV and EV) have been designed and simulated.

II.MODEL DESCRIPTION

The block diagram of the isolated power utility used in this paper is shown in fig .1. the isolated power utility consists of hydro-thermal power plant integrated with PV and EV systems that generate power to fulfil load demand.Mathematical modeling of Inter-connected two-area, power systemintegrated withPVs and EVs(smart grid)have been used where,area-1and area-2consists of hydro-thermal power unit.The transfer function models ofthese

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inter-connected power system are discussed and developed in the IEEE committee report [1-2].

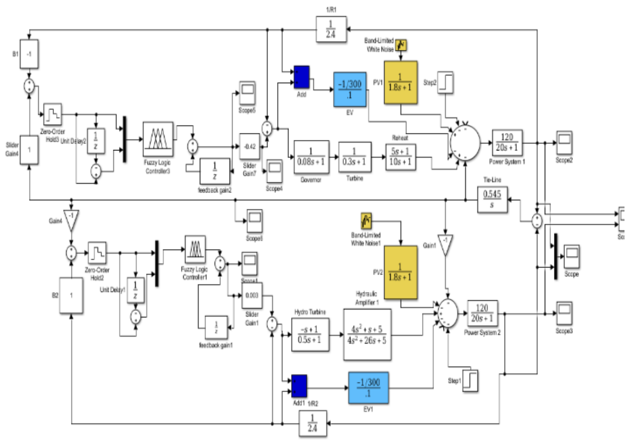

Fig.1. Block Diagram of Two Area Hydro-Thermal Power Systems Interconnected With Smart Grid PV and EV Using Fuzzy Logic Controller. (One hydro and one thermal power system).

III.PROBLEM FORMULATION

Two main objective of this paper are;

1. To develop the power system models for two-area (hydro-thermal) interconnected systems.
2. To integrate distributed power generation systems like PVs and EVs (smart grid) with the above mentioned systems, has been discussed in section II.

The proposed fuzzy logic PID controller is shown in Figure.2. It has two inputs,area control error and change in area control error and one output.

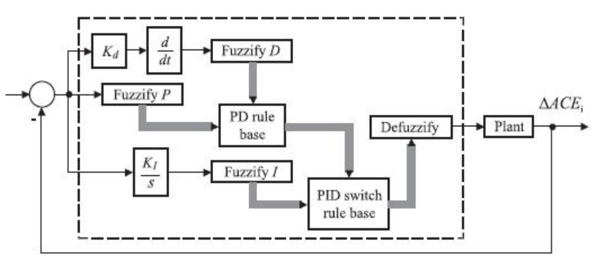

Fig.2. Proposed fuzzy logic PID controller.

In this work,seven membership functions are used.

Table 1 Fuzzy rules for scheduling K_p and K_i.

ACE' \ ACE	LN	MN	SN	Z	SP	MP	LP
LN	LP	LP	LP	MP	MP	SP	Z
MN	LP	MP	MP	MP	SP	Z	SN
SN	LP	MP	SP	SP	Z	SN	MN
Z	MP	MP	SP	Z	SN	MN	MN
SP	MP	SP	Z	SN	SN	MN	LN
MP	SP	Z	SN	MN	MN	MN	LN
LP	Z	SN	MN	MN	LN	LN	LN

These rules play very important role in performance of fuzzy logic controller so in this paper these rules are investigated comprehensively by studying the dynamic behavior of the system. The very popular Mamdani interface system is used in fuzzifying the inputs and combining the fuzzified inputs with the fuzzy rules. The output of the fuzzy system is a fuzzy value and therefore, must be converted to a real value using a suitable defuzzification technique. In this paper, the most effective centre of gravity (COG)' method of defuzzification is used to convert the fuzzy value to real value.

IV.PHOTOVOLTAIC GENERATION SYSTEM

Photovoltaic (PV) cells are made by semiconductor technology to convert solar light energy into electrical energy in the form of Direct Current (DC). The most preferable semiconductor material for manufacturing a PV cell is silicon. PV cell consists of a junction of p and n-doped silicon. A schematic diagram of the cross section view of solar cell (Hille et al 1995) is as shown in Figure.3. When the sun light strikes the junction, the energy in the photons is converted into electrical energy. Since the PV cells do not have any movable parts a longer life with less maintenance can be achieved.

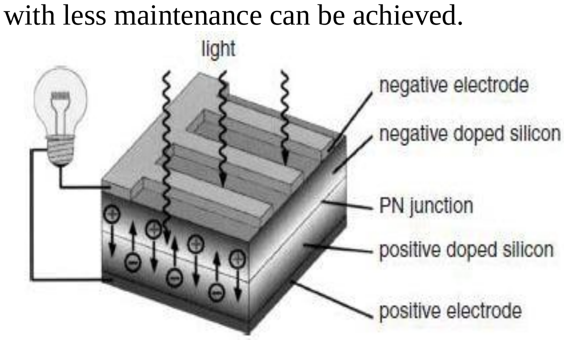

Figure 3 Principle of electricity generation by Sun.

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One of the major drawbacks of the PV conversion system is its huge capital cost and its poor efficiency only in the range of 13% to 16%. But the induction of new technologies in the manufacturing of solar cell, the production cost is reduced significantly. To generate more power, a group of cells called as PV modules or PV array can be connected in series or in parallel to generate more power.

The output power (in watts) of the studied PV system is determined by;

$$P_{PV} = \eta S \Phi \{1 - 0.005(T_a + 25)\}$$

Where η ranging from 9% to 12% is the conversion efficiency of the PV array, S (= 4084 m^{2}) is the measured area of the PV array, Φ (= 1 kW/m^2) is the solar radiation, and Ta is ambient temperature in degree Celsius. The value of PV depends on T_a and Φ because η and S are constant. In this work, T_a is kept at 25 ˚C and PPV is linearly varied with Φ only.

The output current of the solar cell is given by;

$$I_0 = I_L - I_0 \left\{ \exp\left[\frac{q(V_0 + R_{se} I_0)}{KT_k}\right] - 1 \right\} - \left(\frac{V_0 + I_0 R_{se}}{R_{sh}}\right)$$

Where V_0 = output voltage in volts

I_0= output current of the PV in ampere

R_{se} = series resistance of the solar cell in ohms

R_{sh} = shunt resistance of the cell in ohms

q = electron charge (1.6×10^{-19} C)

I_L = Light generated current in amps.

I_d = diode saturation current in amps.

k = Boltzmann constant (1.38×10^{-23} J/K)

T_k = Cell temperature in Kelvin.

As a representative renewable energy source, photovoltaic (PV) generation technology will undoubtedly play an important role in the electricity conversion.Large number of grid-connected PV generation systems are expected to sell their generated electrical power with advantageous price ratings fixed by governmental policies time to time.

V.ELECTRIC VEHICLES (EVS)

From the literature survey it is noted that the electric vehicles (EVs) can have major impact on the power systems dynamic performance. By designing a robust controller, the system can utilize electric vehicles to participate in automatic generation control (AGC) processes, so as to assist conventional thermal power units to respond rapidly and accurately to load fluctuations in uncertain conditions, as well as to enhance the capability of a power system to accommodate renewable energy forms, such as, Photovoltaic Generation System and wind energy.

For the system the transfer function is defined as the ratio of Y(s) to X(s) as shown in equation. Where Y(s) is the output and X(s) is the input of the system. Figure 4 shows the general block diagram of the transfer function of electric motor.

$$G(s) = \frac{Y(s)}{X(s)} = \frac{a_0 s^m + a_1 s^{m-1} + \cdots a_m}{b_0 s^n + b_1 s^{n-1} + \cdots b_n}$$

Where Y(s) is the output variable and X(s) is the input variable. The coefficients a_0 , a_1 , ---------- ,a_n and b_0 ,b_1,------ ,b_m are constants ,and $n \geq m$.

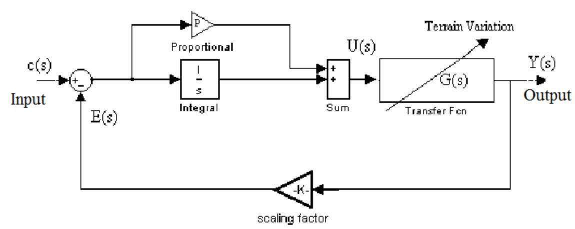

Figure 4 Block diagram of transfer function of electric motor.

The transfer function ω(s)/Ea(s)= G(s)

$$G(s) = \frac{\theta.(s)}{E(s)} = \frac{K_T/L_a}{(J + I_v)s^2 + s(f_0 + f_r) + \frac{K_T K_b}{L_a f_0}}$$

WhereI_v = vehicle Inertia ($kg\text{-}m^2$)

f_r= rolling resistance.

J = moment of inertia of motor ($kg\text{-}m^2$)

f_0 = viscous friction coefficient of motor (Newton-m/rad/sec)

K_T= torque developed by motor (Newton-m)

K_b= back emf constant

R_a/L_a is negligible

The transfer function of the various terrains as obtained is shown in equations.

For concrete;

$$G(s) = \frac{0.913242}{1.39s^2} + 1.215s + 0.913242$$

For medium hard;

$$G(s) = \frac{0.913242}{1.39s^2} + 1.28s + 0.913242$$

For sand;

$$G(s) = \frac{0.913242}{1.39s^2} + 1.5s + 0.913242$$

VI.SIMULATION RESULTS

Lastly the effectiveness of the proposed frequency control method is examined by simulation in Simulink by taking system parameters.

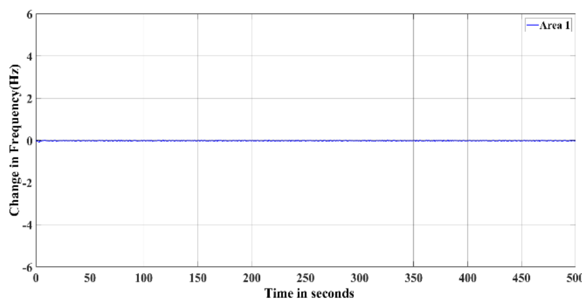

Figure 5 Change in frequency in Area-1

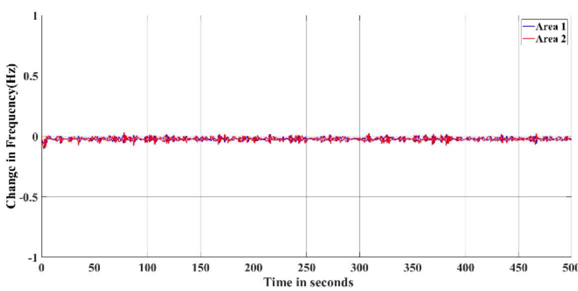

Figure 6 Change in frequency in both the two areas.

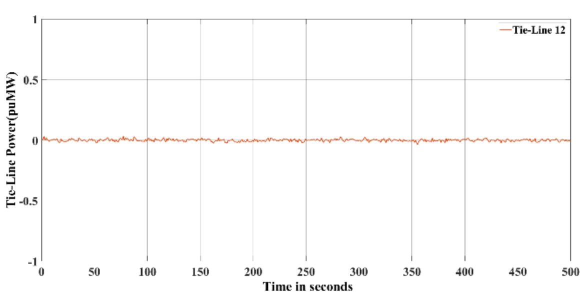

Figure7 Change in Tie-line power in two area.

After evaluating the performance based on the results obtained from different controllers used in studied power system models interconnected with smart grid. It is proved that intelligent fuzzy controller gives better and optimize results related to control of frequency and tie-lie power in the present interconnected power system with smart grid.

VII.CONCLUSIONS

This paper has presents a novel LFC method for isolated power utility connected with PV and EV (smart grid) to regulate and suppress the system frequency change caused by load demands fluctuation e.g. off-peak load etc. Inbrief, both PV and Electric vehicles(smart grid)control approach is effective to reduce deviation in frequency and tie-line power by using fuzzy logic controller.

Appendix A .Parameters of this studied system.

1. Thermal power system

Coefficient of re-heat steam turbine = $k_{r1} = k_{r2} = 0.3$, Re-heattime constants $= T_{r1} = T_{r2} = 10$ s, Turbine time constant $= T_{t1} = T_{t2} = 0.3$ s, R_{thi} Speed governor regulation $= R_{thi} = R_{thi\,2} = 2.4$ Hz/puMW, Speed governor time constant $= T_{g1} = T_{g2} = 0.8$ s and Water time constant $= T_{w1} = T_{w2} = 1$ s, GRC = 0.0017 pu, Dead band = 0.006 pu.

2. Hydro power system.

Speed governor rest time $= T_{R1} = T_{R2} = 5s$ s, Transient droop time constant $= T_{RH\,1} = T_{RH\,2} = 28.75$ s, Main servo time constant $= T_{GH\,1} = T_{GH\,2} = 0.2$ s, and Speed governor regulation $= R_{hy\,1} = R_{hy\,2} = 2.4$ Hz puMW.

3. Power System.

Gain of the power system $= K_{PSI} = K_{PSI} = 120$Hz/pu, Time constant of the power system$= T_{PSI} = T_{PS\,2} = 20$s, Participation factor representing economic load dispatch (pf_{11} = pf21=o.46966, pf12 = pf22=0.37814, pf13 = pf23=0.15220, Bias factor = B1 = B2 = 0.425 puMW/Hz, Integral gains of the controller ($K_1 = 0.6999$&$K_2 = 0.325$).

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