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STABILITY ANALYSIS OF RENEWABLE ENERGY SOURCES WITH HYBRID TECHNIQUE INTEGRATED WITH MOTOR DRIVES

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Abstract: This paper propose a hybrid technique for improving the stability performance of power grid. A hybrid technique is the combination of Recurrent Neural Network (RNN) and Fruit Fly Optimization (FFO) Algorithm, This proposed method will be analyzed on the Motor-Generator Pair (MGP) system based synchronous machines to provide the feasible solution. MGP is a possible technical solution for the stability of renewable energy power systems with high penetration levels. Further studies will focus on, for example, stable operation and feedback control strategies of MGP to deal with random of renewable energy, quantitative cost estimation compared with other solutions, capacity optimization for renewable energy using MGP to achieve grid-connection, excitation system and reactive power control for both sides, coordination control of MGPs, and models and analysis of small signal and transient stability for large grid and a range of different cases.. Initially, the synchronous motor-generator pair system is utilized to connect renewable energy to the grid. For the high penetration of renewable energy, the inertia and damping level, efficiency and cost of the MGP are analyzed for enhance merit of its stability. Then, active power regulation, stability, and frequency response are analyzed. Therefore, the control strategies of the system and the stability performances will be improved and also, the complexity will be reduced with the help of the proposed technique. The proposed technique will be implemented in MATLAB/SIMULINK working platform and the performance will be examined with the traditional methods.

Keywords: renewable energy sources, photo voltaic system, motor-generator set, fruit optimization algorithm

I. Introduction

The photovoltaic energy system has the advantages of absence of fuel cost, no environmental impacts, low maintenance and lack of noise and also it is a kind of renewable energy system. So it is becoming popular in the recent years, as a resource of energy. Modeling and simulation of PV array based on circuit model and mathematical equations are proposed. As the photovoltaic (PV) cell exhibits the nonlinear behavior, while matching the load to the photovoltaic modules, DC-DC power converters are needed. There are several converter configurations such as Buck, Boost, Buck-Boost, SEPIC, ĆUK, Fly-back, etc. Buck and Boost configurations can decrease and increase the output voltages respectively, while the others can do both functions. Buck, Boost, Buck Boost converters as interface circuits are proposed. When the solar insolation and temperature is varying, the PV module output power is also getting changed. But to obtain the maximum efficiency of PV module it must be operated at maximum power point. So it is necessary to operate the PV module at its maximum power point for all irradiance and temperature conditions. Sinusoidal Pulse width-modulated (SPWM) voltage-source inverters (VSI) are widely utilized in ac motor drive applications and at a smaller quantity in controlled rectifier applications as a means of dc to ac power conversion devices, about three quarters of a century of progress in the power electronics field, and about half a century of progress in the microelectronics/macro-electronics and control fields are inherited in the state of the art SPWM-VSI converters. Mostly occurring at different time frames, the breakthroughs experienced in each field have strongly and positively influenced the evolution of today's various types of cost effective, efficient, compact, and reliable high performance SPWM-VSI converters. Since they involve various disciplines of engineering and there has always been a strong demand for them in the market, SPWM-VSI converters have continuously drawn the attention of many researchers all around the world. Therefore, in parallel with this progress, a substantial amount of literature relating to electric converters has been accumulated. In particular, the literature involving the SPWM methods boosting of input voltage.

II. Photovoltaic System

The practical equivalent circuit of a PV module is shown in fig.2. In the equivalent circuit, the current source represents the current generated by light photons and its output is constant under constant temperature and constant irradiance.

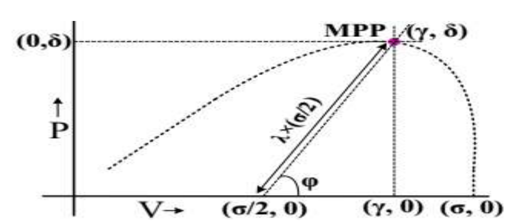

Fig.1. Power-Voltage Characteristic of PV

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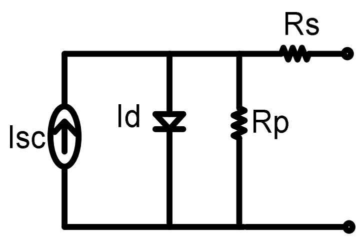


Fig.2.Equivalent circuit of a PV module

The diode shunted with the current source determines the I-V characteristics of PV module. There is a series of resistance in a current path through the semiconductor material, the metal grid, contacts, and a current collecting bus. These resistive losses are lumped together as a series resistor (Rs). Its effect becomes very noteworthy in a PV module. The loss associated with a small leakage of current through a resistive path in parallel with the intrinsic device is represented by a parallel resistor (Rp). Its effect is much less noteworthy in a PV module compared to the series resistance, and it will only become noticeable when a number of PV modules are connected in parallel for a larger system. The characteristic equation which represents the I-V characteristic of a practical photovoltaic module is given below [9].

$$I = I_{PV} - I_o\left[exp\left(\frac{V+IR_S}{V_tN}\right)-1\right]-\frac{V+IR_S}{R_p}$$

Where I and V are the PV cell current and voltage respectively, IPV is the photovoltaic current, Io is the reverse saturation current of diode, Vt = NskT/q is the thermal voltage of the array with Ns cells connected in series, k is the Boltzmann constant (1.3806*10-23J/K), T is the temperature of the p-n junction, q is the electron charge and n is the diode ideality constant. IPV and I0 are given as follows [9].

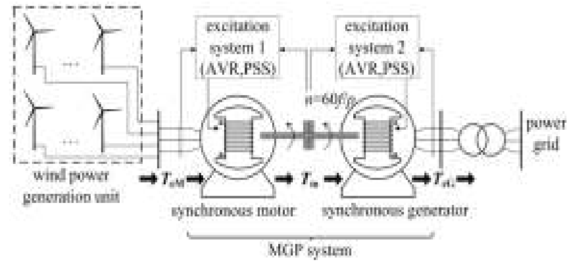
$$I_{pv} = \{[1 + a(T - T_{ref})]I_{sc}\}\left[\frac{G}{1000}\right]$$

$$I_o = I_{o(T_{ref})}\frac{T}{T_{ref}}]^{\frac{3}{n_e}\frac{qE_g}{nk}\left[\frac{1}{T_{ref}}-\frac{1}{T}\right]}$$

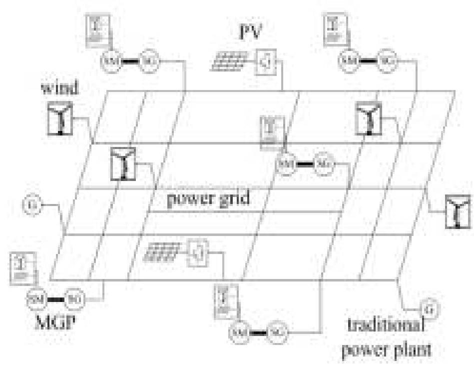
Where “a” is temperature coefficient of Isc, G is the given irradiance in W/m2 and Eg is the band gap energy (1.16eV for Si).

III. Synchronous MGP System For Renewable Energy Integration

The proposed MGP system is shown in Fig.3 (a) [13]. It consists of two synchronous machines, one operating as a motor and the other as a generator. Shafts of the two machines are coupled. Hence, the two machines can rotate at the same speed. The power generated by renewable energy (here are wind turbines) is converged to drive the motor. The motor replaces a steam turbine or a hydro turbine as a primary mover of the generator, which is a main difference from the traditional power generation unit. The converters with different kinds of renewable energy remain the same, which means that there is no need to add a high-capacity converter to drive the MGP.



(a)



(b)

Fig.3. The proposed MGP system: (a) structure of MGP for wind farm integration; (b) a possible configuration of future power grid with MGP.

With the proposed MGP system, Fig.3 (b) depicts a possible configuration of a future power grid with high penetration of renewable energy [12], [13]. One part of renewable energy is still connected to the grid in the traditional way, and another part can use the MGP for integration.The moment of inertia is inherently provided by two synchronous machines. Damping and voltage control can be achieved by excitation systems. In this way, the MGP system can operate as a necessary complement to help future power grids dominated by converters enhance stability.

IV. Modeling Of MGP System For Stability Analysis

A. State Equations Based On Classical Model of Synchronous Machine for Small Signal Stability

In general, the motor and generator in an MGP system should have the same capacity, so the inertia constants are also the same. Hence, equations of motion of the two synchronous machines can be described as

$$\left\{\frac{d}{dt}\Delta\omega_M\right\}=\frac{1}{2H}\left(T_{eM}-T_m-K_{DM}\Delta\omega_M\right) \quad (1)$$

$$\frac{d}{dt}\delta_M=\omega_o\Delta\omega_M$$

$$\left\{\frac{d}{dt}\Delta\omega_G\right\}=\frac{1}{2H}\left(T_M-T_{eG}-K_{DG}\Delta\omega_G\right) \quad (2)$$

$$\frac{d}{dt}\delta_G=\omega_o\Delta\omega_G$$

Where H is the inertia constant; T_{eM} and T_{eG} are electromagnetic torques of two machines; Tm is mechanical torque; δM and δG are rotor angles; ω_M and ω_G are rotor speeds; ω0 is the base rotor electrical speed; KDM and KDG are damping coefficients.

In the analysis of the small signal stability, rotors of different machines are assumed to be made up of a single mass, which also means that ωM = ωG. Hence, the speed equations in (1) and (2) can be added directly

$$\left\{\frac{d}{dt}\Delta\omega_r\right\}=\frac{1}{4H}\left[T_{eM}-T_{eG}-(K_{DM}+K_{DG})\Delta\omega_r\right] (3)$$

To establish the rotor angle equation of the MGP, the rotor angle relationship of this special dual synchronous machine system should be investigated, as shown in Fig.2.

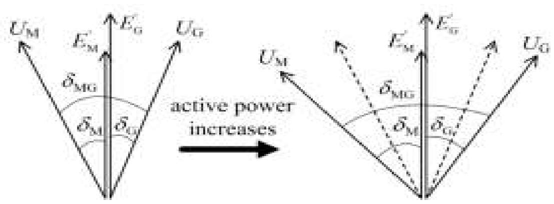


Fig.2. Rotor angle relationship of MGP

$E`_M$ and $E`_G$ represent the internal voltages of motor and generator, and U_M and U_G are the terminal voltages. When ignoring the deviation of the rotor angle position, the relationship of two rotor angles can be expressed as

$$\delta_M+\delta_G=\ \delta_{MG}\ (4)$$

Where δMG also equals the phase difference of bus voltages on both sides of the MGP if they are used as references to measure rotor angles.

For a traditional synchronous machine, the rotor angle changes with the output of active power. (4) Shows that δMG has the same changing trend with δM and δG, which means it has the same changing trend with active power transmitted by the MGP, as shown in Fig.2. Hence, in this paper, δMG is considered an equivalent rotor angle of the MGP for modeling. In addition, a power balance equation of the MGP system is needed (the air-gap torque is equal to the air-gap power in per unit)

$$T_{eM}-T_{eG}=P_{mloss}\ (5)$$

V. Neural Network Techniques

Therefore, the tracking control of the maximum power point is a complicated problem. To overcome these problems, many tracking control strategies have been proposed such as Perturb and Observe, Incremental Conductance [1], Parasitic Capacitance, Constant Voltage, Reactive Power Control, Neural Network [2], Genetic Algorithm (GA), Simulated Annealing (SA), Cuckoo Search Algorithm [3] and Particle Swarm Optimization (PSO) [4] and Fuzzy Logic Controller (FLC) [5]. The PV system can be used either in electric power grid-tied mode or in the stand-alone mode. In grid-tied application, The PV source feeds the high quality AC power into the grid, whereas in stand-alone systems, the generated PV power could drive the stand-alone loads like water pumps [6, 7], heating [8], air compressors, household using additional power sources like battery, fuel cell etc.. [9, 10]. The generated DC power from the PV array is conditioned or transformed into the required form using Power Conditioning Unit (PCU). Also, in such systems PV source can always be operated near Maximum Power Point (MPP) which gives the option of using generated PV power efficiently. Some of the initial solutions for PV pumping system include the use of DC motor without PCU and with a PCU [11]. Here in this paper propose a fruit optimization algorithm control technique which is faster, more effective, more powerful and more stable than the other control techniques.

A. Perturb and Observe (P&O) Algorithm

The P&O is the simplest technique to track the MPP. It is totally based on a change in power (Δρ) and change in voltage (Δϋ) [20]. The positive and negative changes in power and voltage decide the increment or decrement in step size. This step size may be a voltage reference or duty cycle for DC-DC converter.

VI. Fruit Fly Optimization Algorithm

FOA is suggested by When Tsao Pan in 2011 [14, 15]. It is one of the newest optimization algorithms. FOA is developed by inspiring the foraging behavior of fruit flies. Fruit flies are superior to other species in terms of especially smell and vision. They can smell the food even if it is 40 km away. They fly toward to the food according to smell. Then, they can reach the food by using their vision capability. Foraging behavior of fruit fly is shown in Figure 4. FOA is consist of two phases. The first phase is smell phase. In this phase, the flies fly through the food by using their smell capability. After getting closer to the food source the second phase starts. This phase is the vision phase. In this phase they use their vision capability to get nearer to the food. This phase is repeated until the fruit fly reaches the food. The steps of FOA is demonstrated in

Figure 4 and described as follows;

1- Initialization of the parameters (iteration number, fruit fly number)

2- Initialization of the initial positions of the fruit fly swarm (Init X_axis, Init Y_axis)

3- Update the locations of the fruit flies by using smell sensing

$X_i = X_{axis}$ + Random value

$Y_i = Y_{axis}$ + Random value

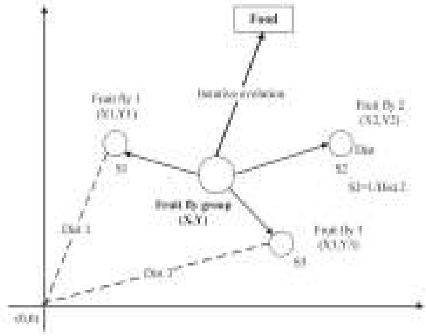


Fig. 4. Food-finding iterative process of fruit fly swarm

A Modified Fruit-Fly Optimization Algorithm Aided PID Controller Designing

This study was published by Yi Liu, Xuejie Wang and Yanjun Li in July 2012. According to the authors, the updating strategy of FOA includes a powerful randomness.

Because of this randomness there can be blindness during the update of the solutions. Thus, convergences rate gets slower and the algorithm can produce unintended results. To cope with this situation a modified FOA was implemented. In this modification chaos search, Particle Swarm Optimization (PSO) and Simulated Annealing (SA) algorithms were used. Chaos search was used for increasing the diversity at the beginning of the algorithm. The diversity at the beginning increases the possibility of getting better results. PSO was used for decreasing the blindness in update procedure and correcting the solution. In order to test the efficiency of this modification, a general function (two dimensional rastrigin function) and a PID were used. According to the simulation results, the modified FOA generates better fitness values then basic FOA. It is faster, more effective, more powerful and more stable than FOA. Because the wave of the best fitness value of MFOA is smaller

VII. Simulation Results

Simulation results shows the performance characteristics of stator currents, rotor speed and mechanical torque developed by the synchronous motor.

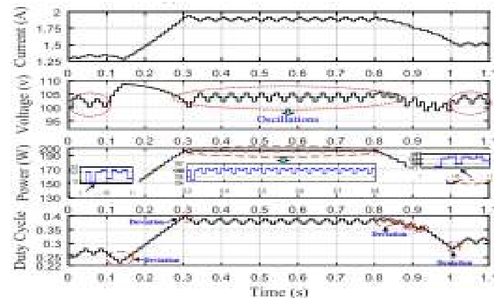


Fig.5. Performances of perturb and observe algorithm during irradiation change in slope

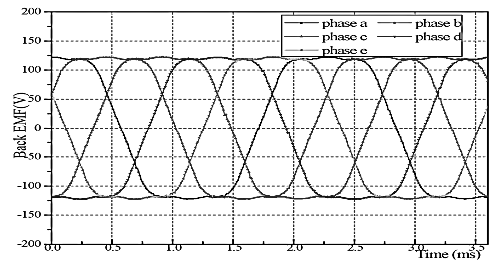


Fig.6.Simulated performance of synchronous motor stator currents

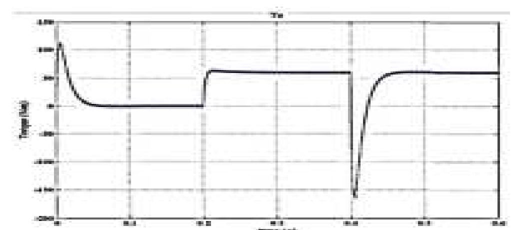


Fig.7.Simulated performance of synchronous motor torque

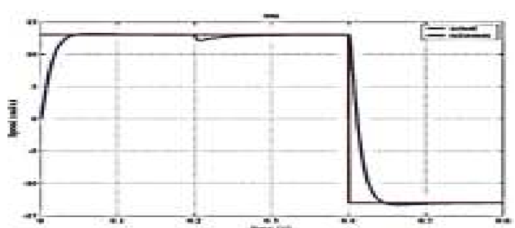


Fig.8.Simulated performance of synchronous motor rotor speed

VIII. Conclusion

In this proposed topology the active power regulation, stability, and frequency response are analyzed.A hybrid technique is the combination of Recurrent Neural Network (RNN) and Fruit Fly Optimization (FFO) Algorithm, This proposed method will be evaluated on the Motor-Generator Pair (MGP) system established synchronous machines to afford the feasible solution. MGP is a conceivable technical explanation for the stability of renewable energy power systems with high penetration levels. Primarily, the synchronous motor-generator pair system is utilized to connect renewable energy to the grid. For the high penetration of renewable energy, the inertia and damping level, efficiency and cost of the MGP are analyzed for enrichits stability. Therefore, the control strategies of the system and the stability performances will be enhanced and also, the convolution will be condensed with the help of the proposed technique

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