Smart control of Parameter of micro grid having renewable sources using fuzzy controller

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Abstract— A new concept in power generation is a micro grid. Isolated micro grid system is a small scale independent power system having renewable energy sources- solar and wind power sources and backup by controllable sources- diesel generator, and fuel cell. The objective of this research is to develop a novel control scheme that can compensate for power and frequency deviation in micro grid. Micro grid consist of renewable sources whose output is not constant. Similarly load on the system is also not constant. Due to these variation power and frequency deviation occurs. For the solution of this situation in this research proposes a scheme called “Smart Control of parameter of micro grid having renewable sources.” The model of this proposed scheme is making out in the MATLAB/Simulink Software (R2012a). In this PID controller is used to control the input parameter of controllable sources according to variation in generation and load and mitigate the problem of power and frequency droop. Participating in Smart Control of Sources. These GRC and P-f droop make the system non linear and we have proposed a Ziegler Nicholas based and Artificial Intelligence based optimization to tune important parameters simultaneously in micro grid. The comparison of Ziegler Nicholas method to tune the PID controller and in the same system Fuzzy controller is use in place of PID. The proposed method improves dynamic and steady– state response of the micro grid and maintains the system frequency at desired level.

Keywords: micro grid, power deviation, frequency deviation.

I. INTRODUCTION

A smart grid is an electricity network that can intelligently integrate the action of all users connected to it- generator, consumer and those that do both- in order to efficiently deliver sustainable, economic and secure electric supply. A smart grid employs innovative products and services together with intelligent monitoring, control, communication and self-healing technologies.

Smart grids co-ordinate the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimising costs and environmental impacts while maximising system reliability, resilience and stability.

A microgrid is a cluster of micro sources, storage system and loads which present itself to the grid as single entity that can respond to central control signal. The heart of the micro grid concept is the notion of flexible, yet controllable interface between microgrid and wider power system. This interface essentially isolate the two sides electrically and yet connects economically.

The application of distributed generation has given rise to many problems, such as protection, control, power quality etc., in the distribution network. Micro-grid, which is the integration of distributed generation and loads, is regarded as a potential solution to the problems mentioned above. Microgrid has become an important supplementary means to solve the many problems of power system in some developed countries. As an important component of distribution network, micro-grid is the necessarily development trend for future, which can not only improve the reliability of power supply, but also ease up the pressure on energy conservation and environmental protection.

In order to utilize the renewable energy cost effectively, many researchers have studied the algorithm to calculate the capacity of applicable generator units that can constitute a reliable power system with low cost. Many different sizing methods, such as iterative method and artificial intelligence method, have been reported to design a techno-economically optimum hybrid renewable energy system.

II. DESCRIPTION OF PROPOSED SYSTEM

A. PHOTOVOLTAIC CELL

Photons of light with energy higher than the band-gap energy of PV material can make electrons in the material break free from atoms that hold them and create hole-electron pairs, as shown in Figure 2-1. These electrons, however, will soon fall back into holes causing charge carriers to disappear. If a nearby electric field is provided, those in the conduction band can be continuously swept away from holes toward a metallic contact where they will emerge as an electric current. The electric field within the semiconductor itself at the junction between two regions of crystals of different type, called a p-n junction.

The PV cell has electrical contacts on its top and bottom to capture the electrons, as shown in Figure 6.1. When the PV cell delivers power to the load, the electrons flow out of the n-side into the connecting wire, through the load, and back to the p-side where they recombine with holes. Note that conventional current flows in the opposite direction from electrons.

![Fig. 1: PHOTOVOLTAIC CELL](image-url)
As temperature increases, the band gap of the intrinsic semiconductor shrinks, and the open circuit voltage (Voc) decreases.

At the same time, the lower band gap allows more incident energy to be absorbed because a greater percentage of the incident light has enough energy to raise charge carriers from the valence band to the conduction band. A larger photocurrent results. The increase in the current for a given temperature rise however is proportionately lower than the decrease in voltage. Hence the efficiency of the cell is reduced.

The simplest model of a PV cell is shown as an equivalent circuit below that consists of an ideal current source in parallel with an ideal diode. The current source represents the current generated by photons (often denoted as I_ph or I_L), and its output is constant under constant temperature and constant incident radiation of light.

![PHOTOVOLTAIC CELL](image)

**Fig. 3: PHOTOVOLTAIC CELL**

There are two key parameters frequently used to characterize a PV cell. Shorting together the terminals of the cell, as shown in Figure 6.2, the photon generated current will flow out of the cell as a short-circuit current (I_sc). Thus, I_ph = I_sc. As shown in Figure 6-3, when there is no connection to the PV cell (open-circuit), the photon generated current is shunted internally by the intrinsic p-n junction diode. This gives the open circuit voltage (Voc). The PV module or cell manufacturers usually provide the values of these parameters in their datasheets. The short circuit (SC) current is directly related to the number of photons absorbed by the semiconducting material and is thus proportional to light intensity. The conversion efficiency is therefore reasonably constant so that the power output is proportional to the irradiance down to fairly low levels, however the efficiency is reduced if the cell temperature is allowed to rise. The open circuit (OC) voltage varies only slightly with light intensity.

![Wind Generation](image)

**Fig. 4: Wind Generation**

1) **Cut in speed**
   At very low wind speeds, there is insufficient torque exerted by the wind on the turbine blades to make them rotate. However, as the speed increases, the wind turbine will begin to rotate and generate electrical power. The speed at which the turbine first starts to rotate and generate power is called the cut-in speed and is typically between 3 and 4 metres per second.

2) **Rated output power and rate output wind speed.**
   As the wind speed rises above the cut-in speed, the level of electrical output power rises rapidly as shown. However, typically somewhere between 12 and 17 metres per second, the power output reaches the limit that the electrical generator is capable of. This limit to the generator output is called the rated power output and the wind speed at which it is reached is called the rated output wind speed. At higher wind speeds, the design of the turbine is arranged to limit the power to this maximum level and there is no further rise in the output power. How this is done varies from 33 design to design but typically with large turbines, it is done by adjusting the blade angles so as to keep the power at the constant level.

3) **Cut-out speed.**
   As the speed increases above the rate output wind speed, the forces on the turbine structure continue to rise and, at some point, there is a risk of damage to the rotor. As a result, a braking system is employed to bring the rotor to a standstill. This is called the cut-out speed and is usually around 25 metres per second.
III. MATHEMATICAL MODEL OF SOLAR AND WIND GENERATION

A. Equivalent Electric Circuit of Photovoltaic Cell

Fig. 5.8 shows the equivalent circuit of the ideal photovoltaic cell. The basic equation from the theory of semiconductors that mathematically describes the I-V characteristic of the ideal photovoltaic cell is:

\[ I = I_{\text{pv,cell}} - I_d \]
\[ I_d = I_{0,\text{cell}} \left[ \exp \left( \frac{qV}{AKT} \right) - 1 \right] \]

where:
- \( I_{\text{pv,cell}} \) is the current generated by the incident light (it is directly proportional to the Sun irradiation).
- \( I_d \) is the Shockley diode equation,
- \( I_{0,\text{cell}} \) is the reverse saturation or leakage current of the diode,
- \( q \) is the electron charge \( (1.60217646 \times 10^{-19} \text{ C}) \),
- \( k \) is the Boltzmann constant \( (1.3806503 \times 10^{-23} \text{ J/K}) \),
- \( T \) (in Kelvin) is the temperature of the p-n junction,
- \( A \) is the diode ideality constant.

B. Mathematical model of WTG

\[ E = W = Fs \]
\[ F = ma \]
\[ a = \frac{v^2 - u^2}{2s} = \frac{v^2}{2s} \text{ (u=0 initial speed)} \]
\[ E = \frac{mv^2}{2} \]
\[ P = dE/dt = \frac{v^2}{2} \text{ (dm/dt)} \]
\[ \frac{dm}{dt} = \rho Av \]
\[ P = \rho Av^3 / 2 \]
\[ P = Cp \rho Av^3 / 2 \text{ (Cp is coefficient of conversion)} \]

The output of solar generation for 1000 w/m² insolation is 0.5 PU and the output of wing turbine generator for 12m/sec speed of wind is 0.36 PU.

As the wind speed increases the output of wind turbine generator increases and solar generation depends upon radiation

IV. FUZZY CONTROLLER

Fuzzy logic is a branch of logic specially designed for representing knowledge and human reasoning in such a way that it is amenable to processing by a computer. Thus, it is applicable to artificial intelligence, knowledge engineering, and expert systems.

Fuzziness pertains to the uncertainty associated with a system, i.e., the fact that nothing can be predicted with exact precision. All real-life situations have some degree of uncertainty or fuzziness. In 1965, Lotfi A. Zadeh introduced fuzzy sets, with which a more flexible sense of membership is possible. However, practically, the value of variables is not always known precisely; rather, approximate values are more likely to be known. In other words, there is an uncertainty or vagueness associated with system variables. One cannot adequately express this uncertainty using a ‘crisp’ variable. The vagueness can adequately be handled using fuzzy set theory. This theory provides a strict mathematical framework using which vague conceptual phenomena can be studied rigorously. In this theory, the variables, functions, etc. Connected with the imprecise phenomenon to be studied are expressed as fuzzy variables and fuzzy functions.

Structure of fuzzy system

A. Fuzzification

To convert crisp value into linguistic variable is termed as fuzzification. For each input and output variable selected, we define two or more membership functions (MF), normally three but can be more. We have to define a qualitative category for each one of them, for example: low, normal or high. The shape of these functions can be diverse but we will usually work with triangles and trapezoids (actually usually pseudo-trapezoids). For this reason we need at least three (for triangles) or four (for trapezoids) points to define one MF of one variable.

1) Types of Fuzzy Reasoning

There are different types of fuzzy reasoning

- (1) Max Dot method.
- (2) Min Max method.
- (3) Tsukamoto’s method

2) Defuzzification

Aggregating two or more fuzzy outputs sets yields a new fuzzy set in the basic fuzzy inference algorithm. Selecting a crisp number \( \mu \) representative of \( \mu (u) \) is a process known as defuzzification. In general, defuzzification is a process in which membership functions are sampled to find the grade of membership; this grade is then used in the fuzzy logic equation and an outcome region is defined, from which the output is deduced.

3) Centre of Area Defuzzification

The defuzzified output is defined as:

\[ u = \frac{\sum_{i=1}^{N} u_i u_{out}(u_i)}{\sum_{i=1}^{N} u_{out}(u_i)} \]

4) Centre of Sums Defuzzification

The defuzzified output is defined as:
\[ u = \frac{\sum_{i=1}^{N} u_i + \sum_{k=1}^{M} u_k(u_i)}{\sum_{i=1}^{N} \sum_{k=1}^{M} u_k(u_i)} \]

5) **Mean of Maxima Defuzzification**

The defuzzified output is defined as:

\[ u = \frac{\sum_{m=1}^{M} u_m}{M} \]

V. **SYSTEM MODEL WITH FUZZY CONTROLLER**

![System model with fuzzy controller](image)

A. **Fuzzy interface system**

Fuzzy inference is a method that interprets the values in the input vector and, based on user-defined rules, assigns values to the output vector. Using the editors and viewers in the Fuzzy Logic Toolbox, you can build the rules set, define the membership functions, and analyze the behaviour of a fuzzy inference system (FIS). The following editors and viewers are provided:

1) **Fuzzy editor**

Displays general information about a fuzzy inference system.

![Fuzzy editor](image)

2) **Membership function editor**

Lets you display and edit the membership functions associated with the input and output variables of the FIS.

![Membership function editor](image)

VI. **DIFFERENT CASES OF SIMULATION**

Case-1: Solar radiation decrease from 1000w/m² to 900w/m² and wind speed will remain same as 12m/s. The load is 0.85pu. The comparison of zigler nicolus method and fuzzy control of tuning gain of PI controller.

A. **Power deviation Curve**

![Power Deviation Curve](image)

B. **Frequency deviation curve**

![Frequency Deviation Curve](image)

Case-2: The speed of the wind is increased from 12m/s to 12.5 m/s and irradiation is 1000w/m² and load is 0.85pu.
C. Power deviation curve

Fig. 15: Power deviation curve

D. Frequency deviation curve

Fig. 16: Frequency Deviation Curve

Settling time for deviation in power and frequency.

<table>
<thead>
<tr>
<th>Case-2</th>
<th>F controller</th>
<th>PI controller</th>
<th>Fuzzy controller</th>
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<tbody>
<tr>
<td>Power deviation</td>
<td>22 sec</td>
<td>24 sec</td>
<td>10 sec</td>
</tr>
<tr>
<td>Frequency deviation</td>
<td>30 sec</td>
<td>23 sec</td>
<td>8 sec</td>
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Fig. 17: Settling Time

VII. CONCLUSION

By using fuzzy controller settling time reduce compare to the PI controller. And to set gain of PI controller by Ziegler-Nicholus method, in each case we have to calculate again and again which is time consuming and tedious work. In fuzzy controller initially we set the gain of membership function and rules of FIS then there is no need to calculate gain again and again the gain.

REFERENCES


