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Micro-Grid Current Imbalance Rate Investigate by Decentralized Generators of Renewable Energy

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--***ABSTRACT***--

In existing micro-grid system, it add the renewable energy power generation by parallel connective such as solar power, wind power and the other equipment to form a new configuration of micro-grid system. Renewable energy power generation is generally divided into single-phase and three-phase connection based on the capacities which feed into the micro-grid of State Grid Corporation of China (SGCC) will form a micro-grid three-phase current balance problem to be concern by both of power supply side and demand side. In this article, set up for 27 decentralized generators (DG) by renewable energy which produce the currents to inject into the micro-grid of to supply share with the currents of loadings. According to the same magnitude of real current as input and base on the average current of three-phase current to calculate the current imbalance rate of each phase such as phase R, S, T and the final average imbalance rate of three phase. It is concerned on the three-phase current balance and the imbalance rate change tendency of the renewable energy generation in connect and disconnect into the micro-grid. There are two cases in this discuss; one for standalone connection and another for parallel connection. With opinions of the average and final imbalance rate of three phase to judge, the parallel connection has better balance results than the balance of the standalone connection.

Keywords *– Imbalance Rate, Decentralized Generator, Renewable Energy, Standalone Connection, Parallel connection.*

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I. INTRODUCTION

Because the oil does not have the characteristic of regeneration and will cause the energy shortage so that countries in the world is strongly promote the development of renewable energy usage and electricity generating to keep the economic growth and humankinds sustain. Only renewable energy has the characteristics of inexhaustible and not pollute the ecological environment and so on which can overcome the depletion of petrochemical energy. The current development of renewable energy are solar energy, water power, wind power , geothermal energy, biomass energy and other natural resources as a source of power generation and every country also has the relevant energy development provision to cope with the problem of energy depletion. Micro-grid, distribution system and power system to transmit power to loading delivery are based on the three-phase type. But in micro-grid due to the loading characteristics and connective type will made the three-phase transmission currents become different and current imbalance.

In order to overcome the unbalanced three-phase problem and many literatures propose solutions like (1) using Bacterial Foraging with Spiral Dynamic (BF-SD) algorithm [1]. (2) using different ways to impose radiality constraint to form the mathematics model ,minimum-loss network reconfiguration network and get results in up to 30% reduction in CPU time for the test systems[2]. (3). Using the ANN modified dynamic fuzzy c-means (dFCM) clustering algorithm to obtain to reconfiguration networks for power loss minimization [3].Network reconfiguration of unbalanced distribution networks using fuzzy-firefly algorithm [4]. (5). with multi-objective distribution feeder reconfiguration to minimize loss by apply the enhanced evolutionary algorithm with o at the presence of distributed generations [5]. (6). Switched capacitor banks and/or fixed banks place to achieve loss minimization. (7). multi-objective management operations based on network reconfiguration in parallel with renewable DGs allocation and sizing for minimizing active power loss [7]. (8) The meta-heuristic methods have been applied in the optimization process due to its excellent capability for searching optimal solution in a complex problem [8]. (9). Use active distribution network (ADN) topology to minimum daily loss cost [9]. (10). Optimized switch placement and Distribution Feeder Reconfiguration (DFR) strategies are applied to the network to investigate the reliability of the system based on failure rate reduction [10]. (11). by DG coordinating the three voltage control methods, namely, power factor control, on load tap changer control and generation curtailment control [11]. Some of the above references use artificial intelligence algorithm, mathematical models to determine the optimal placement or capacity, and the type is fixed or switching of capacitor. That is all of changing the distribution network or power system supporting

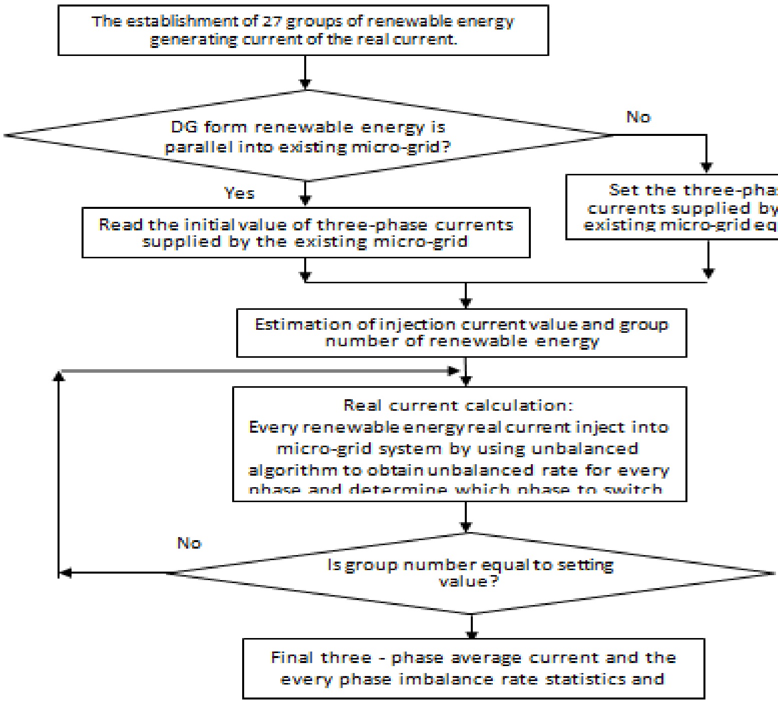

Figure (1) The process of investigate the three-phase imbalance rate process.

network configuration to achieve the best objective function but all those is setting bundle by three-phase for one not base on per-phase. The electricity generated by renewable energy is directly incorporated into the micro-grid which will also cause the current imbalance of the existing micro-grid to intensify or improve so that how use the switch box and algorithm calculation to determine which phase to connect and improve the effect is the focus of study. Figure 1 is the flow chart of this study which according to the same absolute value of complex current and real current fed into the existing micro-grid to investigate the imbalance rate of three-phase. And to compare the three-phase current balance and imbalance rate of the renewable energy generation and considering the power production by renewable energy connected in being micro-grid or not.

II. RENEWABLE ENERGY POWER GENERATION AND EXISTING MICRO-GRID PARALLEL STRUCTURE

Renewable energy power generation system parallel into micro-grid for supply electricity and the government according to the government's renewable energy law to ensure the purchase price so that the belonging of the renewable energy power generation is selected to be power supplier and the load using electricity and in exchange for the maximum profit on its electricity by Figure 2 which is the renewable energy parallel into existing micro-grid metering configuration. Renewable energy power generation is produced DC electricity such as solar power and fuel cell and by converter from the dc convert into AC electricity which is single phase type, generally. It is adopted for three-phase power supply is combi R id connection by single phase converters. Base on single-phase converter from the renewable energy generation into the micro-grid by using the switching box to select which phase to connect and to achieve the purpose of decentralized power generation. If concentrated connective into a phase, it will cause three-phase current significant imbalance in three-phase so that using switching box such as figure 3 to switch to one of the three phases to maintain the balance of the three-phase current.

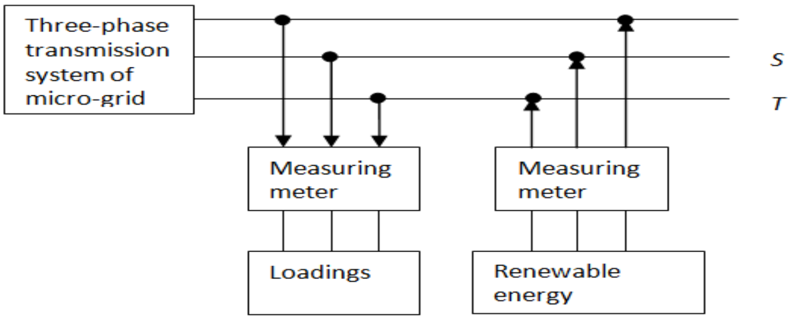

Figure (2) Renewable energy parallel into existing micro-grid metering configuration

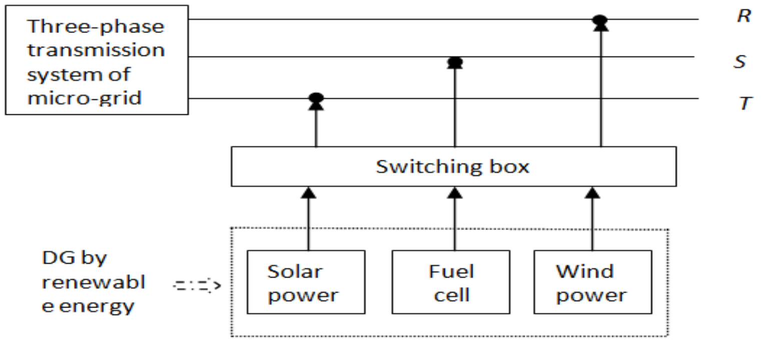

Figure (3) Renewable energy generation connect to switching box structure

III. THREE-PHASE UNBALANCED ALGORITHM TO APPROACH MINIMUM UNBALANCE RATE

Any phase current is complex type that in rectangular axis type which are combination by real part and imagine part and both phase difference equal to 90 electricity degree, and in polar axis type which are combination by magnitude and phase shift such as equation (1). Both axis types can transform each other by equations (2) and (3). So that current use the complex type expression called complex current and current use the magnitude expression called real current.

$$C = C_r + jC_i = |C| \angle \theta \tag{1}$$

$$|C| = \sqrt{C_r^{\,2} + jC_i^{\,2}}, \quad \theta = a\tan^{-1}\frac{C_i}{C_r} \tag{2}$$

$$C_r = |C| \times \cos\theta, \quad C_i = |C| \times \sin\theta \tag{3}$$

Where

C : Complex current

C_r : Real part current in rectangular form

C_i : Imagine part current in rectangular form

$|C|$: Magnitude of current

θ : Phase shift

In fact that the three-phase current of the load in the micro-grid power delivery is actually imbalanced. Looking forward to renewable energy generators fed into one by one into the micro-grid that switch no rules may cause micro-grid three-phase transmission is more uneven and improve the transmission unbalance will have to use selective phase to switch. So how to make the energy generated by the renewable energy dispersive generator use the switching box to incorporate current into one of the three-phase R, S, T to improve the three-phase imbalance is critical. In this article, set up for 27 distribution generators (DG) by renewable energy which produce the currents to inject into the micro-grid. According to the same magnitude of the complex current and real current as inputs and base on the average current of three-phase current to calculate the current unbalance rate. To investigate the unbalance rate varying tendency of both parallel system and standalone system by renewable energy generator injection into micro-grid or not, so that can find solution of the three - phase current imbalance and to improve. The above two cases in the process of solving which is only the first step is different that is the three-phase current in the any phase CR, CS and CT currents set as the initial value . In a parallel system, the CR, CS and CT currents must be supplied by the micro-grid to the load three-phase current as the initial value. In the standalone system, in the CR, CS and CT currents is equal to zero for the initial value set. A total of 27 groups of the renewable energy as DG are sequentially or randomly injected into one of the R, S and T phases of the micro-grid base on the in the minimum imbalance rate.

To reach the unbalance rate of micro-grid is based on the average current of three-phase currents such as equation (4). The phase R, S and T unbalance rate is calculated by equations (5), (6) and (7). And the micro-grid total average unbalance rate of three-phase calculate by equation (8).
rate of three-phase calculate by equation (8).

$$C_{AVG} = \frac{C_R + C_S + C_T}{3} \tag{4}$$

$$UCP_R = \frac{|C_{AVG} - C_R|}{3} \times 100\% \tag{5}$$

$$UCP_S = \frac{|C_{AVG} - C_S|}{3} \times 100\% \tag{6}$$

$$UCP_T = \frac{|C_{AVG} - C_T|}{3} \times 100\% \tag{7}$$

$$UCP_{ALL} = \frac{UCP_R + UCP_S + UCP_T|}{3} \tag{8}$$

Where

C_R : Current of phase R

C_S : Current of phase S

C_T : Current of phase T

C_{AVG} : Average current of three-phase currents

UCP_R : Unbalance rate of phase R

UCP_S : Unbalance rate of phase S

UCP_T : Unbalance rate of phase T

UCP_{ALL} : Average unbalance rate of three-phase

IV. CASE STUDY

Renewable energy DG system is divided into parallel connection and standalone connection to be discussed, respectively. And the general capacity of renewable energy are not large so that the 27 renewable energy power generation are setting be single phase for explore the above two ways renewable energy power generation of the minimum three-phase current imbalance and to determine the renewable energy DG fed into which phase. Those results are based on the magnitude of three-phase currents and not mention on the phase angles.

4.1 Standalone connection

The standalone effect for a renewable energy power generation system means that not conjunction with the power supply by State Grid Corporation of China (SGCC) each other and is only a separate power supply system. Or the power supply network is disconnected for some reason, and only the renewable energy power generation system supplies power independently. In the absence of power provider or called State Grid Corporation of China (SGCC), the three phase currents initial values for CR, CS and CT are equal to zero. In other words, the load is completely supplied by renewable energy generators. This is entirely dependent on the island system where renewable energy is self-sufficient, but the renewable energy generation capacity is small, and the single-phase power source is set to be a three-phase system. So there is also existed the problem of unbalanced three-phase current.

In general, the renewable energy generation of DG is mainly based on a single phase connection which switching field is used to convert the DC power generated by renewable energy sources such as wind power, solar power, or fuel cells into AC power and feed it into the SGCC to achieve goal of minimum imbalance rate of three phase. In standalone system, it is only the optimization of the three-phase balance under supply-demand balance.

Table 1 shows the imbalanced rates of three phases of R, S, T under the conditions of without power provider parallel supply and those are the initial values of CR, CS and CT are equal to zero. The real-time currents of 27 single-phase by renewable energy sources are injected in order. Furthermore, based on the minimum rate of imbalance rate calculated to determine which one phase to switching in.

After 27 DG renewable currents fed in the distribution system and after the all processes calculated the average imbalance rate of phase R is 38.07%, phase S is 40.23% and phase T is 37.95%. And the final results with the imbalance rate for phase R is 3.70%, for phase S is 3.70% and for phase T is 0.03%. Base on the magnitude of three phase current to switching in the three phase line that any phase imbalance rate is gradually reduced by DG of renewable energy input in order and for all distribution system the average imbalance rate of three phase is 2.48% in standalone connection. Such as the figure 4.

Table 1. The each phase imbalanced rates of three phases under standalone connection

Order of input	Average current of three phase (A)	Imbalance rate of phase R (%)	Imbalance rate of phase S (%)	Imbalance rate of phase T (%)
1	4.71	200.00	100.00	100.00
2	8.05	200.00	100.00	100.00
3	11.12	117.10	100.00	17.09
4	15.13	59.52	100.00	40.48
5	22.91	107.19	100.00	7.19
6	35.02	35.52	3.77	39.30
7	59.18	19.80	38.56	58.38
8	62.60	7.78	41.94	49.73
9	70.48	18.09	48.43	66.52
10	82.16	29.73	55.76	85.49
11	84.70	31.84	48.10	79.92
12	105.59	45.32	58.34	103.67
13	139.58	14.42	68.49	54.07
14	172.91	7.64	16.73	24.37
15	179.11	0.45	19.61	20.06
16	207.20	13.94	30.51	44.45
17	214.53	16.88	22.63	39.51
18	224.73	20.66	12.53	33.18
19	242.13	4.80	18.81	23.61
20	262.13	10.83	25.01	14.18
21	285.19	1.87	06.81	4.95
22	296.60	9.48	10.36	0.91
23	303.77	6.89	12.51	5.62
24	325.45	19.76	18.34	1.42
25	337.94	15.33	10.27	5.06
26	356.27	9.40	14.89	5.49
27	375.84	3.70	3.70	0.03
Average imbalance rate (%) of each phase		38.07	40.23	37.95
Final average imbalance rate (%) of three-phase			2.48%	

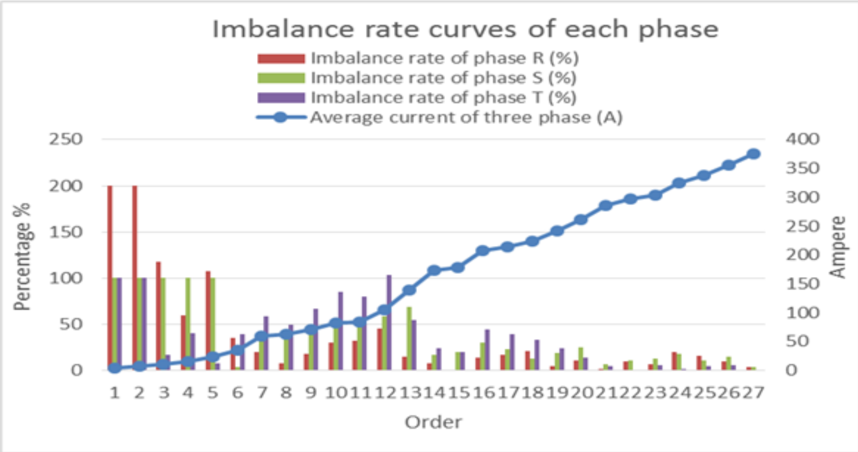

Figure (4) Each phase imbalance rate curves of three phase in standalone system

4.2 Parallel connection

Sale behavior of power suppliers that use decentralized power generation systems by using renewable energy to generate electricity in parallel with the SGCC that guaranteed purchase price is based on the law of renewable energy and this purchase price is higher than the price charged by the SGCC. Therefore, in this case, it alternative is to sell the electricity produced by the renewable energy to the SGCC and power consumption of loading by demands are buy form the SGCC. Which obtain the dual profits of the difference between of power consumption from the SGCC price charged and purchase price, and the power generation sailing of renewable energy to achieve the biggest profit on produced electricity suppliers by renewable energy. The generation of general renewable energy is mainly in single phase. In this case, the initial load of the SGCC is setting with the initial value, which is adjusted by the switchyard to achieve the purpose of three-phase current balancing. In the parallel system which is necessary to consider the optimization of the minimum unbalanced rate for the three phases and phases of the existing initial load of the SGCC. From the view of actual situation, the function of switching box is switched to one of the three phases to maintain the balance of the three-phase currents. In the Parallel system, the CR, CS and CT initial currents are decided by the existing loading of SGCC. In other word, the existing loading of three phase may be near to balance or significant imbalance. Furthermore said, the initial current of each phase in three phase are not equal to zero that is very strong different with the standalone connection.

Table 2 shows the imbalanced rates curves of three phases of R, S, T under the conditions of power provider parallel supply and those are the initial values of CR, CS and CT are not equal to zero. The real-time currents of 27 single-phase by renewable energy sources are injected in order. Furthermore, based on the minimum rate of imbalance rate calculated to determine which one phase to switching in.

After 27 DG renewable currents fed in the distribution system and after the all processes calculated the average imbalance rate of phase R is 16.95%, phase S is 13.82% and phase T is 20.13%. And the final results with the imbalance rate for phase R is 0.08%, for phase S is 0.2% and for phase T is 0.12%.

Base on the magnitude of three phase current to switching in the three phase line that any phase imbalance rate is gradually reduced by DG of renewable energy input in order and for all distribution system the average imbalance rate of three phase is 0.13% in parallel connection. Such as the figure 5.

V. CONCLUSION

The main purpose of this article is to research the renewable energy power generation system whether in SGCC or not and to discuss the three-phase current balance and imbalance ratio by using the switching box parallel-connected to which phase of SGCC through the minimum imbalance rate calculation to determine.

According to the real situation base on the current magnitude as the criterion and calculate the imbalance rate of each phase of three phase to decide which phase to fed into when the DG of renewable energy generation is fed in system. That will made the three-phase current unbalance ratio will be lower and lower to reach the balance of the three phase so that the generated electricity can be used efficiently and the end user can obtain better power quality.

Table 2. The each phase imbalanced rates of three phases under parallel

Order of input	Average current of three phase (A)	Imbalance rate of phase R	Imbalance rate of phase S	Imbalance rate of phase T
1	29.71	34.62	14.90	49.52
2	33.05	21.04	3.31	24.35
3	36.12	36.26	5.48	30.79
4	40.13	22.64	14.93	7.71
5	47.91	2.74	28.74	26.00
6	60.02	18.00	17.43	0.57
7	84.18	41.53	16.27	57.80
8	87.60	32.10	19.54	51.64
9	95.48	12.96	26.17	39.13
10	107.16	10.25	34.22	23.97
11	109.70	7.69	28.78	21.09
12	130.58	9.53	7.80	1.72
13	164.58	28.22	14.46	42.68
14	197.91	40.31	21.66	18.65
15	204.11	42.12	17.96	24.16
16	232.20	12.83	3.69	9.14
17	239.53	15.50	9.70	5.80
18	249.73	18.95	17.48	1.48
19	267.13	4.69	9.83	5.13
20	287.13	9.57	2.17	11.74
21	310.19	1.42	16.88	18.30
22	321.59	2.17	12.74	10.56
23	328.77	2.24	10.27	12.52
24	350.45	14.47	3.45	17.93
25	362.94	10.53	10.22	20.75
26	381.27	5.22	4.92	10.14
27	400.84	0.08	0.20	0.12
Average imbalance rate (%) of each phase		16.95	13.82	20.13
Average imbalance rate (%)			0.13	

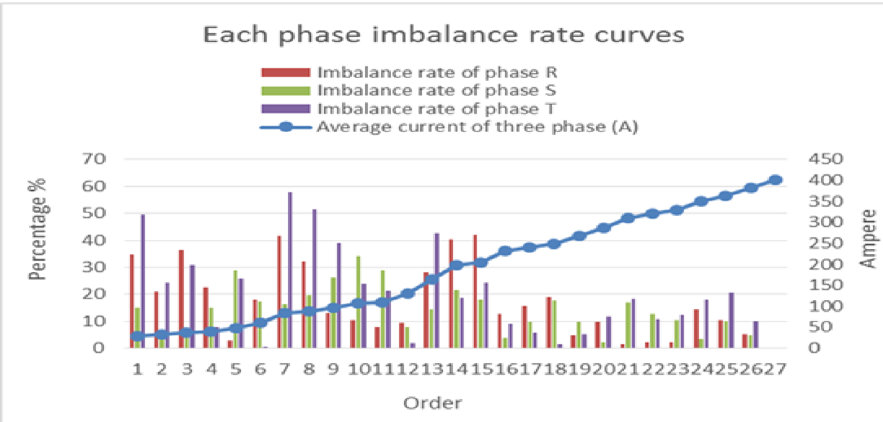

Figure (5) Each phase imbalance rate curves of three-phase in parallel system

The real-time currents of 27 single-phase by renewable energy sources are injected in order. Furthermore, based on the minimum rate of imbalance rate calculated to determine which one phase to switching in.

1. After 27 DG renewable currents fed in the distribution system and after the all processes calculated the average imbalance rate of phase R is 38.07%, phase S is 40.23% and phase T is 37.95%. And the final results with the imbalance rate for phase R is 3.70%, for phase S is 3.70% and for phase T is 0.03%. Base on the magnitude of three phase current to switching in the three phase line that any phase imbalance rate is

gradually reduced by DG of renewable energy input in order and for all distribution system the average imbalance rate of three phase is 2.48% in standalone connection.

2. After 27 DG renewable currents fed in the distribution system and after the all processes calculated the average imbalance rate of phase R is 16.95%, phase S is 13.82% and phase T is 20.13%. And the final results with the imbalance rate for phase R is 0.08%, for phase S is 0.2% and for phase T is 0.12%. Base on the magnitude of three phase current to switching in the three phase line that any phase imbalance rate is gradually reduced by DG of renewable energy input in order and for all distribution system the average imbalance rate of three phase is 0.13% in parallel connection.

Compare both of the three imbalanced rates of standalone and parallel connections to the SGCC. With opinions of the average and final imbalance rate of three phase to judge, the parallel connection has better balance results than the balance of the standalone connection.

The analytical result is that there is an initial value in the parallel connection and when the DG of renewable energy generator is fed into one phase of three phase of the SGCC made jumping slope of current imbalance rate in the SGCC is smaller cause the final three-phase imbalance rate is also smaller. In other words, this case has better three-phase balance .In contrast, in the case of standalone connection due to the three phase initial current is set to zero and when the DG of renewable energy generator is fed into one phase of three phase of this isolation region and jumping slope of current imbalance rate in the area of power provider is bigger cause the final three-phase imbalance rate is also bigger that say the three-phase balance of the micro grid of the region of standalone connection is not good.

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Biographies and Photographs

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