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A Novel Islanding Detection Method for DG Power Systems using Combined Chaos Theory and DQ Transformation

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Abstract – **The customer demand for better power quality and higher reliability has forced the power industry to use distributed generations (DGs) such as wind power and photovoltaic arrays. Islanding occurs when a power grid becomes electrically isolated from the power system and the distribution system is energized by distributed generators. It is necessary to disconnect all distributed generators immediately after islanding occurrence otherwise it causes a number of safeties, power quality and system integrity problems, therefore a DG system should have the capability to detect islanding phenomena. In this paper a novel islanding detection method using combined chaos theory and DQ transformation is proposed. The simulation results using MATLAB software verify the proper operation and effectiveness of the proposed method.**

Keywords – **Islanding Detection Method, DG Power System, Chaos Theory, DQ Transform.**

I. Introduction

In the last twenty years electrical consumption has been increased in the worldwide [1-3]. The investment on hydro and nuclear power plants has been very limited in recent years [4, 5]. Distribution generation (DG) has become an effective alternative to bulk electric power generation [6]. The energy of DG is renewable and can handle the peak load demands properly. The construction of new power plants and upgrading of transmission lines due to steadily increasing demand will take significant cost and time thus distributed generators can assist in reducing cost and time by strengthening power grids near their stability limits [7, 8]. Distributed generators are classified to three categories as follows: induction, synchronous and asynchronous generators [9]. Induction generators need external excitation and start up like an induction motor and they are used in wind power applications. Synchronous generators need a DC excitation and they should be synchronized before connection to the network. Synchronous generators are used in gas turbines and small hydro power plants. Asynchronous generators are inverter based systems and are used in micro turbines, photovoltaic and fuel cells [9]. Some of advantages of using DGs are as follows [9, 10]:

(a) Flexibility.
(b) Improved Reliability.
(c) Improved Security.
(d) Reduced loading and losses of transmission and distribution system.
(e) Improved power quality and voltage profile of the system.

One of the most significant challenges with a DG system is the protection against unplanned islanding. Islanding is a phenomenon occurs when a power grid becomes electrically isolated from the power system and the distribution system is energized by distributed generators. It is necessary to disconnect all distributed generators immediately after islanding occurrence. Therefore a DG system should have the capability to detect islanding phenomena. The IEEE 929-1988 standard [11] requires the disconnection of DG once it is islanded also IEEE 1547-2003 [12] standard allows a maximum delay of two seconds for detection of unplanned islanding and all DGs disconnection from the distribution network. Some of drawbacks of islanding operation of DGs are as follows [9, 13, and 14]:

(a) Line worker safety threatening.
(b) The voltage and frequency drifts.
(c) Out of phase reclosing of DGs.
(d) Degradation of electric components.

The islanding detection techniques are shown in Fig. 1. In this paper a novel islanding detection method using combined chaos theory [15] and DQ transformation [16] is proposed. The simulation results using MATLAB software verify the proper operation and effectiveness of the proposed method.

II. Detection Principle Based on Chaos Theory [15]

As a matter of fact, the defect or islanding condition in passive detection method can be achieved according to the characteristics of the parameters sensitivity of chaotic system. The islanding detection based on chaotic system has the following characteristics [15]:

1. Chaotic time-domain system is a time domain detection method which small changes in system parameters lead to a radical phase change therefore it can detect the small changes of signal parameters after islanding occurrence, so it has higher sensitivity compared with traditional passive methods.
2. Chaos detection system can detect occurrence of islanding real timely and quickly, which is based on overvoltage and under voltage islanding detection method. When a DG is connected to the electrical grid, the normal range of electrical network voltage is from 88 to 110

percent of rated voltage as depicted in Table 1. As electric network voltage is beyond the normal operating voltage range, the islanded DG system should be disconnected in specific time immediately as shown in Table 1.

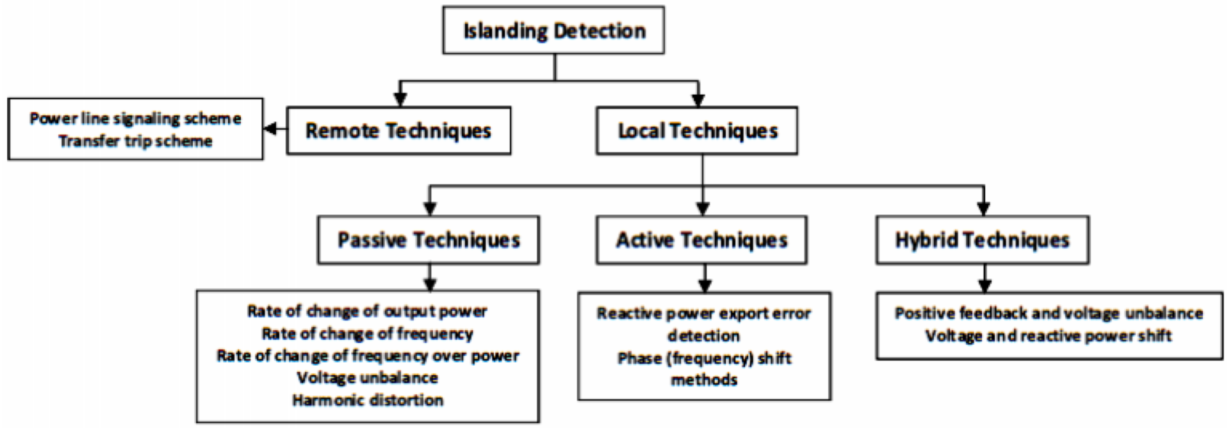

Fig.1. Islanding detection techniques

Table1. The response time of abnormal DG system voltage [15]

The area of voltage (PCC point)	The maximum response time(periods)
V<50%	6
50%≤V≤88%	120
88%<V<110%	normal operation
110%≤V≤137%	120
V>137%	6

The kinetic equation for describing nonlinear elastic system is used to produce chaos phenomenon as below [15]:

$$\frac{d^2x}{dt^2}+k\frac{dx}{dt}-ax^3+cx^5=h\sin(\omega t) \qquad (1)$$

The chaos system as described in equation (1) is used for islanding detection. The parameter h is fixed at 0.725524 and other parameters are chosen as following: a=c=1, k=0.5 and ω=1 rad/s, therefore the following equation is obtained [15]:

$$\frac{d^2x}{dt^2}+0.5\frac{dx}{dt}-x^3+x^5=0.725525\sin(t) \qquad (2)$$

When the voltage amplitude is beyond the voltage limits of DG system the periodic chaos states is changed therefore, comparing the phase chart of chaotic system with initial chaotic system can be used to diagnose DG islanding phenomenon.

III. Detection Principle Based on DQ Transformation [16]

The electrical network encountering power quality disturbances such as voltage dip, over voltage, harmonic distortion and frequency variations so it is necessary to detect islanding conditions to protect in confronting these disturbances. The DG system is required to be protected in over/under frequency and over/under voltage conditions. The power balance equations for a DG power system as shown in Fig. 2 are written as follows:

$$P_L=P_{DG}+P_S \qquad (3)$$

$$Q_L=Q_{DG}+Q_S \qquad (4)$$

The behavior of the power system when islanding occurs depends on P_S and Q_S. Active power is directly proportional to the voltage. After is landing phenomenon the load active power is forced to be the same of DG system therefore the voltage amplitude is given by [16]:

$$V^*=kV \qquad (5)$$

Where k is defined as follows:

$$k=\sqrt{\frac{P_{DG}}{P_L}} \qquad (6)$$

When $P_{DG} > P_L$ there is an increase in voltage amplitude however if $P_{DG} < P_L$ there is a decrease in voltage amplitude. Reactive power is tied up to voltage amplitude and frequency by the following equation [16]:

$$Q_L^*=Q_{DG}=(\frac{1}{w^*L}-w^*C)V^{*2} \qquad (7)$$

A small change in active power results in small voltage amplitude fluctuations also a small change in reactive power results in small voltage frequency fluctuations and leads to effectively disconnecting the islanded DG power system. The phase locked loops (PLLs) are mainly designed for monitoring parameters before and after islanding occurrence. The voltage vector is synchronized using a PLL and using the DQ rotating frame transformation the frequency and amplitude of the voltage are estimated. A low pass filter is required to extract the exact voltage amplitude and frequency. The following equations are used in DQ frame transformation.

$$\begin{bmatrix}V_q\\V_d\\V_0\end{bmatrix}=\frac{2}{3}\begin{bmatrix}\cos\theta & \cos(\theta-120) & \cos(\theta+120)\\ \sin\theta & \sin(\theta-120) & \sin(\theta+120)\\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2}\end{bmatrix}\begin{bmatrix}V_a\\V_b\\V_c\end{bmatrix} \qquad (8)$$

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$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta-120) & \sin(\theta-120) & 1 \\ \cos(\theta+120) & \sin(\theta+120) & 1 \end{bmatrix} \begin{bmatrix} V_q \\ V_d \\ V_0 \end{bmatrix} \quad (9)$$

$$|V_a| = |V_b| = |V_c| = \sqrt{V_d^{\,2} + V_q^{\,2} + V_0^{\,2}} \quad (10)$$

This method is based on monitoring of voltage amplitude and frequency, when an islanding phenomenon occurs, during islanding transient there would be significant changes in voltage amplitude and frequency because DG becomes the only source in islanded power system.

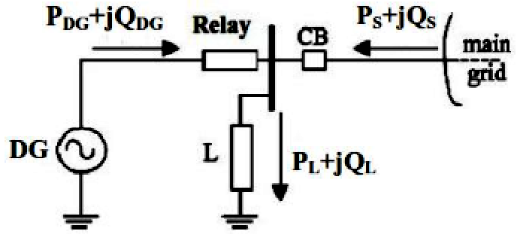

Fig.2. Equivalent circuit of a DG power system

IV. Proposed Method and Simulation Results

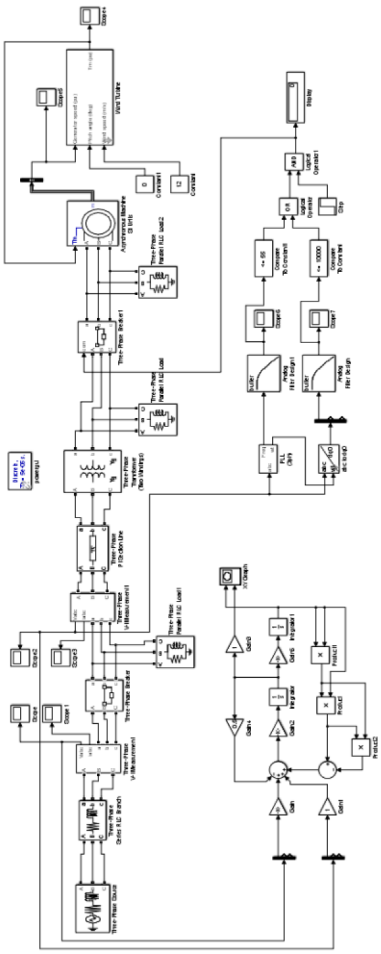

Fig.3. Power system topology and proposed control strategy

As a matter of fact two methods described in section II and III are combined to constitute a novel redundant and reliable methods for islanding detection of DG power systems. The power system topology and proposed control strategy using MATLAB/SIMULINK software is depicted in Fig. 3.

The phase chart of chaotic system in normal operating condition is shown in Fig. 4, whereas during islanding phenomenon the phase chart of that chaotic system will be as depicted in Fig. 5. As shown in Fig. 3, DQ transformation blocks are used to send trip signal to DG system circuit breaker relay. Assuming the islanding phenomenon has occurred in 0.5 seconds of simulation time, the output trip signal of DQ transformation blocks is shown in Fig. 6.

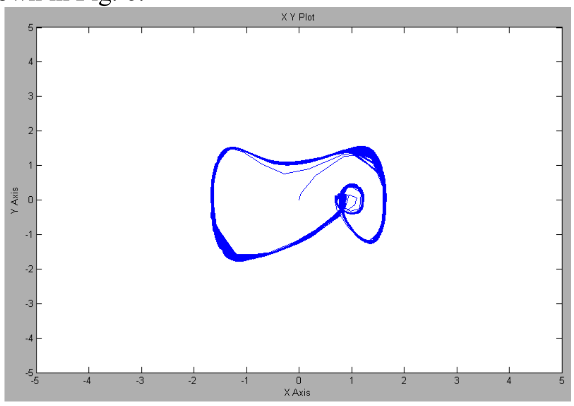

Fig.4. Phase chart of system in normal operating condition

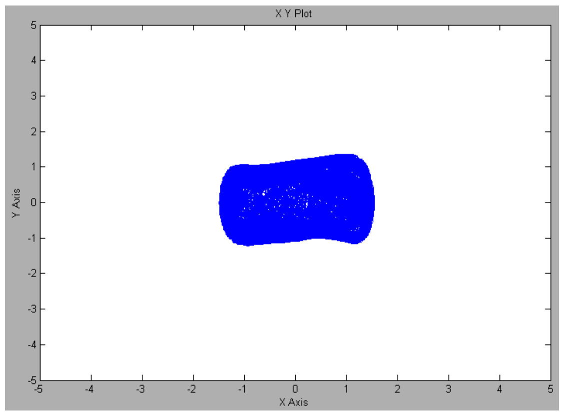

Fig.5. Phase chart of system during islanding phenomenon

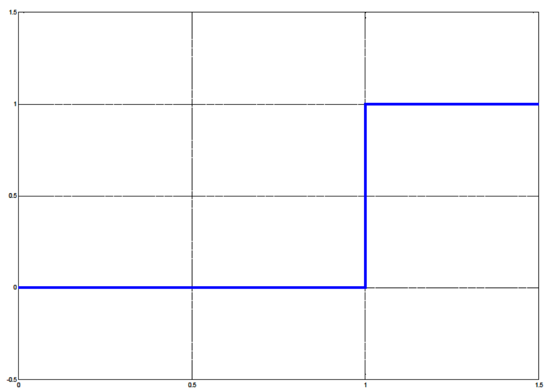

Fig.6. Trip signal of DQ transformation blocks for an islanding phenomenon at 0.5 seconds

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V. Conclusion

Islanding occurs when a power grid becomes electrically isolated from the power system and the distribution system is energized by distributed generators. It is necessary to disconnect all distributed generators immediately after islanding occurrence otherwise it causes a number of safeties, power quality and system integrity problems, therefore a DG system should have the capability to detect islanding phenomena. In this paper a novel islanding detection method using combined chaos theory and DQ transformation was proposed. The simulation results using MATLAB/SIMULINK software verified the proper operation and effectiveness of the proposed method.

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