# INTENTIONAL ISLAND OF DISTRIBUTION NETWORK

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## *ABSTRACT*

*This paper presents an investigation of intentional island in a distribution network of the Provincial Electricity Authority (PEA), Thailand. Presently, there is an increase of small power producers (SPPs) or distributed generations (DGs) interconnected to the distribution network following the government policy in electricity generation using renewable energy or combine heat and power (CHP). An advantage of DG is to improve the system reliability by maintaining power with acceptable voltage and frequency to the significant load. Besides, DG could operate as a backup generator. When the utility system is down, DG can supply power to cooperative customers directly. Therefore, an intentional island, which is a situation that the DG or group of generators continues to supply the local load that has been separated from the utility grid, is employed to supply power to a group of critical customers in the distribution network of the PEA. The system performance: voltage and frequency, of intentional and accidental islanding condition is investigated by DIgSILENT program. Three cases with assuming fault occurred in each protective relay zones are studied. The results obtained show that the system is stable with conditions, which will be discussed in detail.*

## 1. INTRODUCTION

The distributed generation (DG) has continuously been introduced and promoted around the word because of privatization and liberalization in power sector. Furthermore, high efficiency, friendly environment, low investment costs and short construction time are advantages of DG. Presently, there is an increase of the electric generation using renewable energy such as solar, wind, biomass, biogas etc in Thailand because of the Royal Thai Government (RTG) policy and promotion such as pricing subsidy and employing a principle of net-metering and TOU (Time of Use) for very small power producer (VSPP). Moreover, Thailand has stipulated a national renewable portfolio standard (RPS) or the share of renewable energy utilization as fuel in power generation. This RPS target, applied only to new power plants, is currently set at 5% i.e. 5% of the new installed power generation capacity must be renewable energy [1].

There are positive and negative impacts of DG connection on the distribution system. DG can improve the system performance such as loss, voltage regulation, reliability etc. In contrast, it may effect on the power quality and protection coordination [2-7]. In addition, a case study of distribution network supplied by multiple DGs and grid sources with considerable transmission line length is investigated in [8]. It indicates that there are problems of reliability, network losses and voltage regulation. The analyses results suggested that local generations have strong influence on system losses and system voltage regulation.

To improve the system reliability of critical customers, the island is applied to these loads. Island is a condition in which a portion of an Area Electric Power System (EPS) is energized solely by one or more Local EPSs through the associated point of common couplings (PCCs) while that portion of the Area EPS is electrically separated from the rest of the Area EPS [9]. There are many papers and standard concerning the island. To protect the generator, anti-islanding methods are developed and discussed as mentioned in [10-12]. The benefit of island to keep energy supply is important.

To increase reliability and power quality of distribution network, the concept of island supplied by DG is applied to system with cooperative customer. Moreover, it could encourage the power generation using renewable energy according to government energy policy because of increased SPP connection time.

The paper presents an intentional islanding investigation of PEA's distribution network. A case study supplied by a distributed generation with intentional islanding condition is examined using DIgSILENT program. The paper starts briefly with power purchase policy and small power producer and very small power producer status providing power to distribution network. The system performance: voltage and frequency of islanding condition are examined. Finally, recommendations are given in detail.

## 2. POWER PURCHASE POLICY

Since 1992 the RTG has been promoting private sector investment in the electric power generation business in order to increase the efficient operation, to encourage the use of indigenous by-product energy sources and renewable energy for electricity generation and to alleviate the government's investment burden of generation and distribution system. Power purchases from SPP with selling capacity not exceeding 90 MW is one of the important measures employed to achieve the target. In 2002 the government approved the regulation of power purchasing from VSPP using renewable energy with selling capacity not exceeding 1 MW and the guideline for VSPP interconnection to distribution network (As of 2006, it was enlarged from 1 to 10 MW) [13]. The net metering and time of use (TOU) principles are used in this case. More recently in August 2003, the Ministry of Energy had launched a "Strategic Plan to Promote New and Renewable Energy Technology Development. An increase of renewable energy share in the country fuel mix from 0.5 % in 2002 to 8% by 2011 is set as a target [1].

## 3. CURRENT STATUS OF SPP AND VSPP

As of September 2006 [14], there are a total of, from 113 approved SPPs, 79 SPPs currently in operation, as shown in Table 1, and selling power to the grid at 22 kV, 69 kV, 115 kV and 230 kV. The total installed capacity is 4,152.11 MW and the total generation selling to the grid is 2,337.50 MW. From 79 SPPs, there are 68 SPPs which connected to PEA's distribution system (Remaining SPPs are under responsibility of the Metropolitan Electricity Authority: MEA). The number of Firm and Non-Firm contracts is 37 and 42 respectively. These power plants are classified by fuel types into 3 categories, namely;

- Commercial: Natural gas, fuel oil and coal
- Non-conventional: Bagasse, rice husk, hydro, biogas etc. and
- Mixture of the two fuel types.

Table 1 Current Status of SPP

| Fuel Type | No. of SPP | Installed Capacity (MW) | Power Sale to Grid (MW) |
|---|---|---|---|
| Commercial | 26 | 2,680.21 | 1,670.20 |
| Non-Conventional | 49 | 995.90 | 434.30 |
| Mixed Fuel | 4 | 476.00 | 233.00 |
| **Total** | **77** | **4,152.11** | **2,337.50** |

The most common energy type is the commercial type as shown in Table 1. Its installed capacity and power sold to the grid are 2,680.21 MW and 1,670.2 MW respectively. The power supplied to the grid of non-commercial energy type is more than for the mixed fuel type (434.3> 233 MW).

Table 2 Current Status of VSPP

| Fuel Type | MEA | | PEA | | Total | |
|---|---|---|---|---|---|---|
| | No. | Power Sale to Grid (kW) | No. | Power Sale to Grid (kW) | No. | Power Sale to Grid (kW) |
| 1. PV | 43 | 6.50 | 22 | 59.80 | 65 | 66.30 |
| 2. Wood Chips | - | - | 1 | 400.00 | 1 | 400.00 |
| 3. Paddy Husk | - | - | 5 | 3,235.00 | 5 | 3,235.00 |
| 4. Palm Residue | - | - | 3 | 3,000.00 | 3 | 3,000.00 |
| 5. Straw | - | - | 6 | 1,030.00 | 6 | 1,030.00 |
| 6. Biogas | 1 | 950.00 | 15 | 8,180.00 | 16 | 9,130.00 |
| Total | 44 | 956.50 | 52 | 15,904.80 | 96 | 16,861.30 |

There are a total number of 96 VSPPs using renewable energy with total power sale to grid of 16.86 MW interconnected to distribution system as demonstrated in Table 2. It is found that a large number of VSPP is PV systems (roof top) with small size and biogas respectively. They are increasing because of government energy policy promotion mentioned.

## 4. ISLAND

An island is a condition that local generator supply power to a segment of local load or distribution system as given in Fig.1 [15]. Its cause may be intentional or unintentional. The first one is purposely opening of upstream switch that could perform the island. On the other hand, an operation of upstream device as a fault results in intentional island. However, all situations make island.

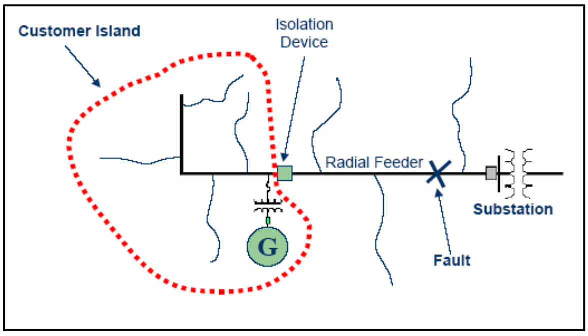



Fig.1 Intentional Island

In some area, the distribution system is connected with DG. The DG must have load following capability and sufficient voltage regulation capability for the type of loads on the island. Typically, synchronous generators have been used for this application. Therefore, the system reliability will be improved by DG. From the Fig.1, an upstream automatic switch is used to island a section of a distribution feeder. The switch must open during upstream faults and the generator must be able to carry the load on the islanded section, maintaining suitable voltage and frequency levels at all islanded loads. Unless a static switch is employed, this diagram would usually result in a momentary interruption to the island since the DG would necessarily trip during the voltage disturbance caused by the upstream fault. A DG assigned to carry the island must be able to restart and pickup the island load after the switch has opened. Thus, in the next section, to ensure that the island can enhance the system reliability, case studies are investigated.

## 5. CASE STUDY

From the increase of DG and system reliability enhance, the island is employed to the distribution system with critical customer. A case study consists of 115 kV grid source, one 22.5 MW DG (SPP) and 115/22 kV substation, which is PEA's distribution loads as shown in Fig.2. The DG using renewable energy (rice husk) with firm contract (25 years) is connected to 115 kV system through a 25.6 MVA unit transformer between source and substation at 7.7 km from source. It sells a power of 20 MW to grid, which the commercial operation date starts on 21 Dec 2005.

The distance from DG to substation is 23 km. The substation has 10 feeders supplying power to customers through a 50 MVA power transformer, which peak and light load is 16 MW and 8 MW respectively.

The type of automatic voltage regulator (AVR) and turbine are obtained from DG manufacture data sheet. The parameters are modeled by using the typical value from DIgSILENT library.

Therefore, three cases of the system stability in islanding condition are investigated using stability function from the program. The intentional and unintentional island is happened when the protective device operates as three-phase fault occurred or planned manual switch open in the position of (see Fig.2):

- Case 1: between source and DG (zone1)
- Case 2: between DG and substation (zone2)
- Case 3: at the line of substation load feeder (zone3)

The voltage, frequency, power and speed of generator and system voltage and frequency are monitored.

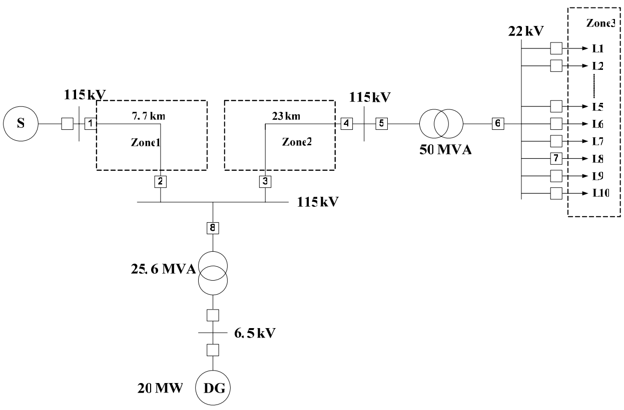



Fig.2 Simplified Model of Case Study

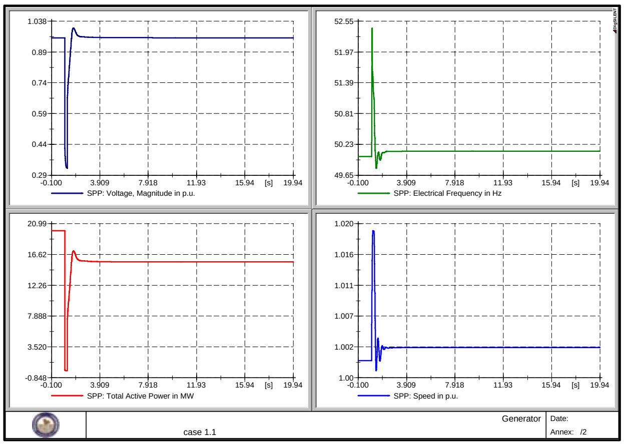
## 6. RESULTS

The results obtained from the system investigation of three cases can be discussed as follows;

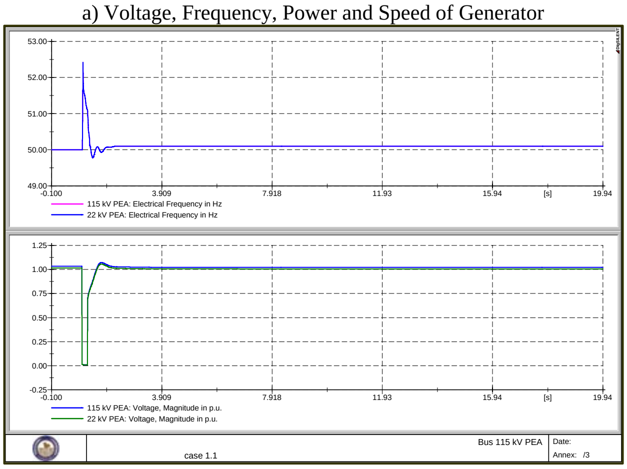
**Case1**, the island is performed by a three-fault fault or intentional open of switch.

- Case 1.1, a fault happened at zone1.

When a fault occurred, CB1 and CB2 opened. Thus, the system performs the island. The results obtained are shown in Fig.3. It is clear that voltage and frequency of generator (SPP) is stable and can restore in few second after the island occurred. In the same way, the voltage and frequency of 115 and 22 kV bus is stable.




a) Voltage, Frequency, Power and Speed of Generator




b) Frequency and Voltage of 115 kV and 22 kV Bus

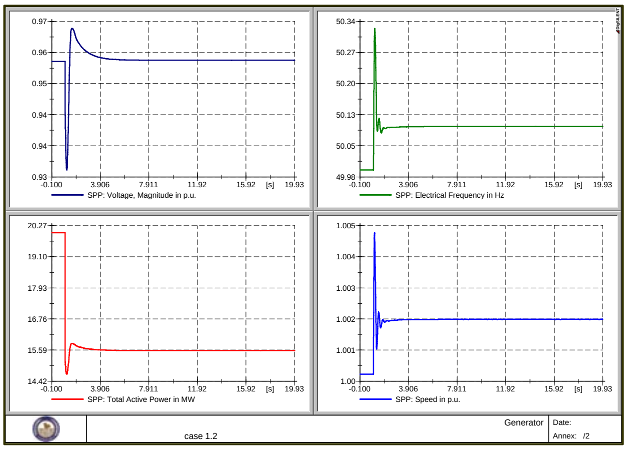
Fig.3 Simulation Results of Case 1.1

- Case 1.2, an intentional island by opening CB2 at zone1.

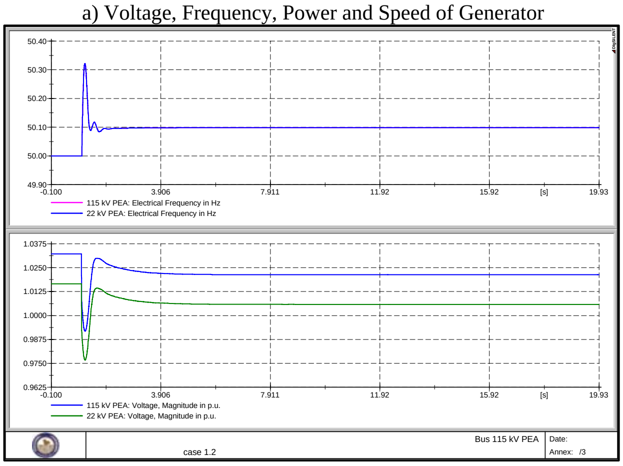
The system remains stable after CB2 of DG opened and the result obtained is shown in Fig.4. The power is decreased from 20 MW to roughly 16 MW following the load in island. The frequency and speed of generator is slightly changed. However, they keep on the limit.

Therefore, in this case1 DG is stable and it can supply power to the critical load with acceptable frequency and voltage.

**Case2**, this case aims to study the intentional island behavior with a fault occurred. Firstly, the system is running in the island, which CB2 opened. Then, a fault is placed in the system at zone2. The CB3 of DG is opened at time of 1.1 sec to clear such fault and automatically reclosed to energize the system load at time of 3.1 sec. As a result, the system is collapsed according to the voltage, frequency, power and speed of generator and system voltage and frequency as given in Fig.5.Therefore, in this case, the DG can not withstand the fault current in the island because the fault is close to DG, which fault level is high.




a) Voltage, Frequency, Power and Speed of Generator



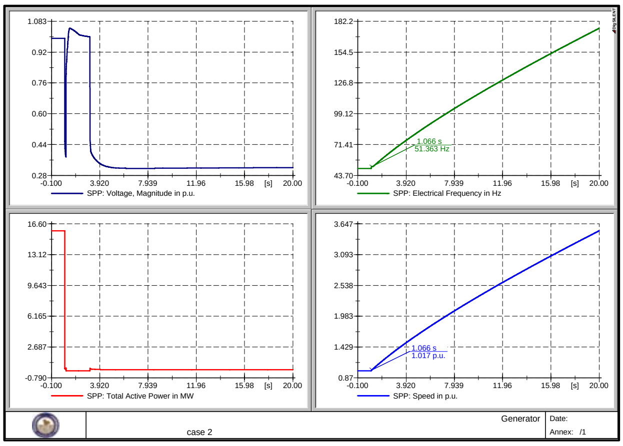

b) Frequency and Voltage of 115 kV and 22 kV Bus

Fig.4 Simulation Results of Case 1.2

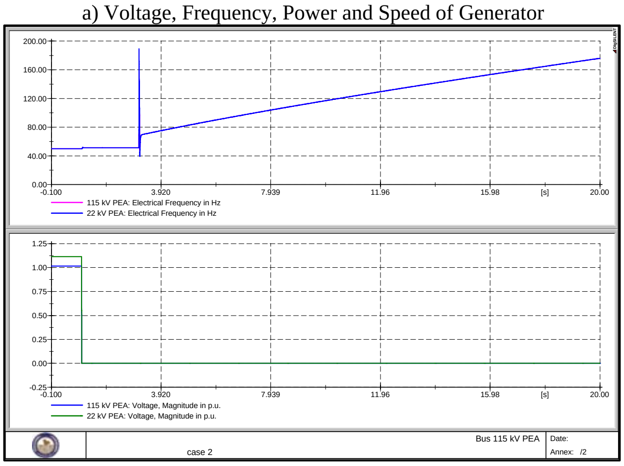
**Case3**, the intentional island with a fault at zone3, is studied. The performance of island obtained is illustrated in Fig.6. The system is running at islanding mode, which CB2 opened. Then, a fault is occurred in feeder 8 or L8 at distance of 7.5 km far from the substation. From Fig.6, it shows that the system is stable. DG can supply power to local load when CB7 of L8 is opened. In this case, the fault position is far from DG. Thus, the fault level is low.

## 7. CONCLUSION

The paper presents an intentional island investigation of PEA's distribution network. A case study with a distributed generation operated in intentional island is examined. The system performance during system transformation from normal condition to an island with unintentional and intentional island is performed. The result obtained shows that the system is stable because DG can response and supply power to the system load. Moreover, the behavior of island as fault occurred is investigated. DG can continue to supply power in case of CB open to clear fault at remote distance. In contrast, DG cannot operate if fault occurred close to DG because the fault level is very high. Therefore, the distribution system with DG can be formed as intentional island with conditions and more investigation such as generator parameter, control system etc. The island can be applied to distribution system with cooperative customer that requires high power quality and reliability.

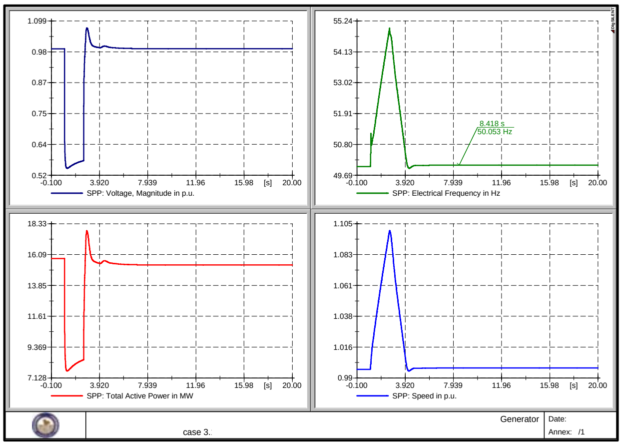



a) Voltage, Frequency, Power and Speed of Generator

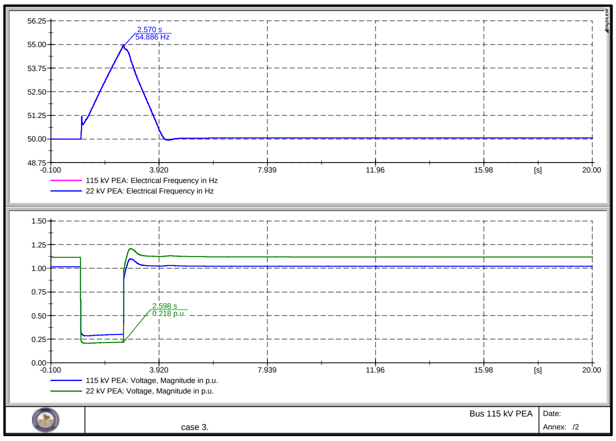



b) Frequency and Voltage of 115 kV and 22 kV Bus

Fig.5 Simulation Results of Case 2




a) Voltage, Frequency, Power and Speed of Generator




b) Frequency and Voltage of 115 kV and 22 kV Bus
Fig.6 Simulation Results of Case 3

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