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Design of Control Logics for Islanding Schemes in Thermal Power Plants

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Abstract: This paper focuses on the design of control logics for islanding schemes for three thermal power stations in Rajasthan, India. Islanding occurs when a power plant is isolated from the main utility grid, and this research seeks to design an algorithm for control logics for islanding schemes, develop a load-shedding scheme to stabilize the power system, and investigate planned islanding on rural feeders with multiple distributed generation units. The paper begins by defining islanding and its importance in ensuring uninterrupted power supply during grid disturbances. The research reviews various techniques used for the detection and classification of islanding events, including deep learning, wavelet transform, and fuzzy logic, highlighting the significant research activity in this area. The proposed control logics are based on the concept of decreasing frequency due to heavy load and low generation, and at a pre-determined frequency, boundary transmission lines will trip, and local loads will be fed from the local generator. Under-frequency relays are used to sense major grid disturbances and initiate load scheduling prior to islanding. The design of islanding schemes and load flow studies are also discussed to find balance between loads and generation. The research shows that islanding can offer advantages such as uninterrupted power supply in the island during grid disturbances and easier restoration of the island compared to the whole system from a blackout. Therefore, the development of effective islanding control logics is crucial for ensuring reliable and stable power supply. This study presents a comprehensive study of the design of control logics for islanding schemes for thermal power stations in Rajasthan. The proposed algorithm and load-shedding scheme provide a practical approach for ensuring stable power supply during grid disturbances, while the investigation of planned islanding on rural feeders with multiple distributed generation units offers valuable insights into the feasibility of implementing such schemes in similar contexts.

INTRODUCTION

Islanding is the event where a power plant is isolated from the main utility grid, and local loads are being supplied by the plant. This can be either intentional or unintentional. Intentional islanding is used to create a power "island" during system disturbances, while unintentional islanding is not planned[1]. The formation of islands for thermal and nuclear power plants has been considered in recent blackouts to continuously feed critical loads[2] . Techniques for islanding detection are classified as passive, active, or remote (communication-based) methods[3].

The network of Rajasthan Rajya Vidyut Prasaran Nigam Ltd. (RVPN) consists of conventional generators such as thermal power plants, nuclear power plants, and hydel power plants, as well as renewable energy sources. The objective of the research work discussed in this thesis is to design control logics for islanding schemes for Kalisindh thermal power station (KaTPS)[4, 5], Supercritical Suratgarh thermal power station (SC-STPS), and Rajwest lignite thermal power station (LTPS). The contribution of the research includes formulating an algorithm for designing control logics for islanding schemes, designing a load-shedding scheme to stabilize the power system, and investigating planned islanding on rural feeders with multiple distributed generation units[6].

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The classification, pros, and cons of islanding detection methods are presented in Table 1.1[1], and the generation schedule, GSSs, and transformer capacity of the Rajasthan transmission system are provided in Tables 1.2, 1.3, and 1.4, respectively."

Table 1.1 A comparison between the islanding detection methods

S. No.	Methods	Pros	Cons
1	Passive	Incorporate the passive method with signal process techniques and pattern recognition enables fast islanding detection and immunization to system parameter changes	Cannot detect islanding if source and load are balanced; cannot detect islanding with 30+% power mismatch
2	Active	Usually have smaller NDZ than passive methods	Need to inject a disturbance, which alter the system
3	Communication based	Can eliminate NDZ; suitable for a system with multiple DERs	Requires additional communication capability
4	Hybrid	Flexible to employ various methods together	Complexity of the methods may add burden to computation

Table 1.2 Generation schedule of Rajasthan transmission utility

S. No.	Type of generation	Generation capacity (MW)
1	Thermal power plants	7861.64
2	Nuclear power plants	1612
3	Hydro power plants	267.12
4	Solar power plants	5287.10
5	wind power plants	4194.3712

Table 1.3 GSSs in Rajasthan transmission system

S. No.	Voltage level (kV)	Total number of GSSs
1	765 kV	4
2	400 kV	27
3	220 kV	122
4	132 kV	451

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Table 1.4 Transformer capacity in Rajasthan transmission system

S. No.	Voltage level (kV)	Total transformer capacity (MVA
1	765/400kV	13,500
2	400/220kV	21,740
3	220/132kV	29,875
4	132/33kV	31,720

LITERATURE REVIEW

Islanding refers to the phenomenon where a part of a power system is disconnected from the main grid, but continues to operate as an isolated system. This literature review provides an overview of various techniques used for the detection and classification of islanding events. The review includes 9 papers that employ different methods such as deep learning, wavelet transform, and fuzzy logic, among others, to classify islanding events[7]. One of the papers reviewed[7] provides a comprehensive overview of different techniques and schemes for islanding detection and compares the non-detection zone (NDZ) and speed of detection of these methods. Another paper[8] introduces a deep learning approach for classifying islanding and grid disturbances, which uses a hybrid combination of wavelet transform, multi-resolution singular spectrum entropy, and deep learning architecture. Other papers propose approaches that combine multiple methods such as random forest and moth flame optimization[9], voltage and current unbalance with the wavelet transform and artificial neural network[10], and the artificial neural network and support vector machine[11].

Several papers propose novel methods for islanding detection based on different features of the power system such as the frequency response[12], reactive power [13, 14], and voltage-controlled inverter supported distributed generator[15]. These methods demonstrate a low non-detection zone and high detection speed and can effectively detect islanding in various operating conditions.

The literature review suggests that there has been significant research activity in the area of islanding detection, and various methods have been proposed to detect and classify islanding events. The methods proposed in the reviewed papers have shown to be effective in detecting islanding with a low non-detection zone and high detection speed in various operating conditions.

METHODOLOGY

There are various methods to detect the grid disturbances to initiate islanding scheme. One such method is to sense the grid frequency[16]. Grid frequency is directly related to load. If the load on grid increases, the frequency will go down. However, in case of decrease in load, the grid frequency will increase. One major cause of grid disturbance is unbalance in generation and load. Mismatch between the two will result in change in frequency from 50Hz. Therefore, under frequency relay is employed to sense major grid disturbances and initiate load scheduling by opening designated feeders, prior to islanding, to sense generation Rich Island. Low grid frequencies in combination of power flow towards grid initiates islanding and hence simultaneous tripping of all pre-defined lines to make an island. Once, the island is formed, it is very important to control the frequency of generation unit and maintains load generation balance in the island for successful survival after the islanding.

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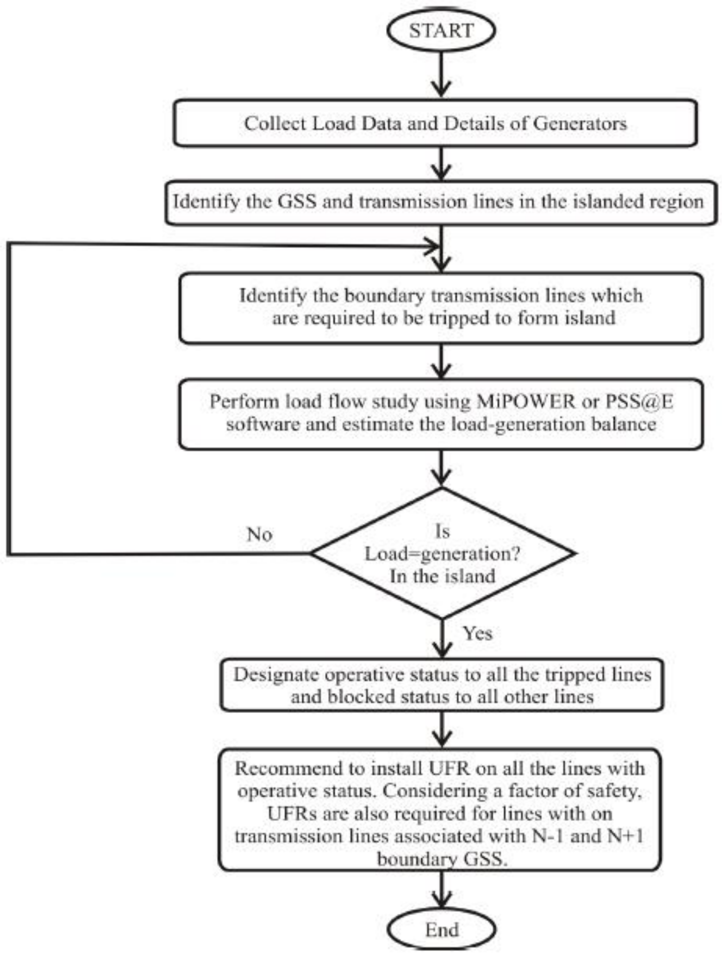
Proposed control logics are based on the concept of decrease in frequency due to heavy load and low generation. This scenario occurs when the generation units start tripping one by one in the cascade fashion and load remains connected. At pre-determined frequency, boundary transmission lines will trip and local load will be fed from the local generator.

The main advantages of island are that power supply is not interrupted in the island even during the grid disturbance. This will help to supply start up power to various power plants to restore the system. Restoration of island is quite easier when compared to restoration of whole system from blackout[17] .

The generalized method used to design islanding schemes for generators at KaTPS, SC-STPS and Rajwest LTPS is illustrated in Fig. 1.1[18]. Load data including the strategic and critical loads are collected. Grid-substations (GSS) and associated transmission lines which are likely to be included in the islands are identified. Network is designed in the MiPower or PSS@E softwares.



Load flow studies are performed to find out balance between the loads and generation. If there is difference between the load and generation, then the load flow study is repeated by changing the status of lines from operative to blocked and vice versa. Under frequency relays (UFR) are recommended for the lines with operative condition when load-generation balance is met. Further, for the purpose of safety factor installation of UFR is also recommended for the transmission lines associated with N-1 and N+1 boundary GSS. This will help to meet the load-generation balance considering seasonal and daily variations of load[18].

Case Study 1: Design and Implementation of Islanding Scheme for Kalisindh Thermal Power Plant

The Kalisindh Thermal Power Plant (TPS) is a power station located in the Baran and Jhalawar region of India. The power plant consists of two generation units, each rated at 600 MW, with an interconnecting transformer (ICT) rated at 315 MA, 400/220 kV, used to feed the local loads in the region. An islanding scheme is required for a load of 330 MW, the maximum load which can be fed through the ICT. This chapter describes the existing transmission network and generation power plants in the region, including the Chhabra TPS, Chhabra supercritical TPS, and Kawai TPS. The total generation capacity of these four thermal power plants is 4840 MW. The power generated by these plants is pooled to the 765 kV GSS Anta through a 400 kV transmission line, from where it is evacuated to the Jaipur region through the 765 kV D/C Anta-Phagi transmission corridor.

To design an islanding scheme for the Kalisindh TPS, several operational constraints need to be considered, including the overloading of the 315 MVA, 400/220 kV ICT at Kalisindh TPS if the system is operated in the ring system continuously. To obviate overloading of the ICT, the Rajasthan State Load Dispatch Centre (SLDC) operates the system in radial mode by opening several lines. In the islanding operation scenario, the 220 kV Modak-Bhawani Mandi Line and 220 kV Jhalwar-Modak Line are required to be operated in the ring system. One generation unit of Kalisindh TPS is required to be tripped to form the island.

To design the control logic for the islanding scheme, a load flow study was conducted using the PSS@E software. The results of the study are detailed in this chapter. The final control logics proposed for the Kalisindh TPS island are also discussed in detail. These control logics ensure that the generation unit is operated at a reduced load as soon as the islanding takes place, to achieve the goal of feeding a load of 330 MW through the ICT.

In this case study, the requirement of an islanding scheme for the Kalisindh TPS, including the existing transmission network and generation power plants in the region. Several operational constraints need to be considered when designing the islanding scheme, such as the overloading of the 315 MVA, 400/220 kV ICT at Kalisindh TPS. The final control logics proposed for the Kalisindh TPS island ensure that the generation unit is operated at a reduced load as soon as the islanding takes place, to feed a load of 330 MW through the ICT.

Case Study2: Islanding Scheme for Supercritical Suratgarh Thermal Power Plant

Supercritical Suratgarh Thermal Power Plant (SC-STPS) is a power generation unit with two 660 MW generation units, providing a net dispatch of 617 MW after meeting the auxiliary load. All evacuating transmission lines from SC-STPS are rated at 400 kV voltage level, and there is a 400 kV D/C interconnecting line between SC-STPS and STPS power plants. This chapter details the requirement of an islanding scheme for the SC-STPS, including the existing transmission network, a load flow study using the MiPower software, and proposed final control logics for the SC-STPS island.

Existing Transmission Network:

An interconnecting transformer (ICT) rated at 315 MA, 400/220 kV is installed at STPS, which is used to feed local loads in the region. Two units of 250MW rating at STPS are connected on the 220 kV voltage level, and four units of 250MW are connected on the 400 kV voltage level. Power from the SC-STPS is evacuated to the Suratgarh, Ratangarh, and Bikaner region through the 400 kV and 220 kV lines. There is a 400 kV D/C STPS-Ratangarh line, and five 220

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kV lines emanating from the STPS, which are used to feed power in the surrounding areas. 220 kV GSSs are situated at Suratgarh, Hanumangarh, Udyogvihar, Padampur, Rawatsar, and Halsar. These GSSs are interconnected through 220 kV transmission lines and used to feed power to the local load in the region.

Load Flow Study:

A load of 618 MW can be designed for the islanding scheme, and to achieve this goal, one generation unit is required to be operated at full load, and another generation unit is required to be tripped as soon as islanding takes place. The identified load around SC-STPS is 600 MW, and the main load concentrated at each 220 kV GSS in the region is detailed. Seasonal variations of load are high in the region, with a maximum load of approximately 725 MW observed in the summer season (April-August) due to high agriculture load and a minimum load of approximately 300 MW observed in the winter season (December-January).

Final Control Logics:

To maintain stability in the system, some of the transmission lines are designed to be in both operative/blocked modes during the islanding scheme. The final control logics proposed for the SC-STPS island are discussed in detail in this chapter.

The islanding scheme is required for the SC-STPS with a load of 618 MW. The existing transmission network is detailed, and a load flow study using the MiPower software is performed. Proposed final control logics for the SC-STPS island are discussed in detail, and some of the transmission lines are designed to be in both operative/blocked mode to maintain stability in the system. Seasonal variations of load are high in the region, with a maximum load of approximately 725 MW observed in the summer season (April-August) due to high agriculture load and a minimum load of approximately 300 MW observed in the winter season (December-January).

RESULTS

The algorithm developed in this study has successfully designed control logics for the formation of islands in the KaTPS, SC-STPS, and Rajwest LTPS power plants. The control logics for the transmission lines using under frequency relays (UFRs) to form islands by load-generation balance have been designed and implemented. The study has also highlighted the importance of transient condition calculations for generator unit islanding, which significantly depends upon a variation of the load power. Furthermore, the study has established that the choice of emergency control automation for the islanded power grid is critical to ensuring its load stability. Control logics have been designed to form islands of Kalisindh TPS, SC-STPS and Rajwest LTPS in Rajasthan. Load flow study was performed using PSS@E and MiPower software on the All India database and database of Rajasthan State. Load generation balance for each island can be maintained by tripping the lines with operative status and keeping the transmission lines in blocked status as operative. This is achieved by the under frequency relays (UFRs) installed on the transmission lines included in the Islands.

CONCLUSION

The design of control logics for islanding schemes in thermal power plants is an important step towards improving the stability and resilience of the power grid. This study has successfully developed an algorithm to design control logics for the formation of islands in three thermal power plants in Rajasthan. The control logics have been designed to operate the transmission lines using under frequency relays (UFRs) to form islands by load-generation balance. The study highlights the importance of transient condition calculations and emergency control automation for islanded

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power grids to ensure load stability. The findings of this research can be applied to other power plants, contributing to the overall stability and reliability of the power grid. Continuous monitoring of load-generation balance is required and action to change status of UFRs from blocked to operative and vice-versa will be needed for load-generation balance which can be monitored by the SLDC of Rajasthan. Proposed control logics to form islands of Kalisindh TPS, SC-STPS and Rajwest LTPS have been designed based on the results of load flow study. However, at the time of formation of islands, there are heavy grid disturbances. Hence, it is required to perform transient stability studies before practical implementation of proposed control logics.

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