Improvement of Defense Scheme Operation by Considering Load Profile of Interbus Transformer for Sub Java Electrical System

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Abstract. The electrical blackout on August 4, 2019, in several areas of Jakarta and surrounding areas took a long time to recover and the vital loads lose electrical supply. This power outage indicates that there is a weakness in the electrical defense scheme. Based on the conventional standard, when the frequency declines due to a fault in the power system, several buses must release loads without considering existing load circumstances. The impropriate scheme for load shedding will trigger a catastrophe as the capacity of the electrical source is limited. In the subsystem of the large electrical network, several groups of loads are supplied by an inter-bus transformer which accepts electrical energy from other networks and generators. As the transformer has limited capacity and the transmission network's characteristics are strongly influenced by the line parameters and the energy passing through, then this paper proposes a defense scheme that considers the combination of real and existing loads carried by the IBT and the rate of frequency decline. It is expected that the proposed scheme will prevent the power system fall into a worse situation, accelerate recovery conditions and maintain the frequency profile. The work takes a sub-Java electrical system with two inter-bus transformers included.

Keywords: Electrical Blackout · Load Shedding · Electrical Defense Scheme · Underfrequency Relay

1 Introduction

Several countries have experienced blackouts over the last decade. In July 2012, India experienced a blackout that affected 670 million consumers [1]. This was caused by an overload transmission network. The blackout in West Sulawesi, Indonesia, on December 2, 2014, was caused by a Pare – Sidrap transmission interruption due to a flashover. The 500 kV Ungaran – Pemalang interconnection network encountered a problem on August 4, 2019, which prevented it from transmitting power from east to west, resulting in a blackout on Java Island [2].

An effective electric power system must be able to keep the supply of electrical power when a disturbance occurs. These disturbances can be caused by various things, such

N. I. Inda et al. (Eds.): ISST 2022, APR 7, pp. 114–121, 2023.
https://doi.org/10.2991/978-94-6463-228-6_14

as lightning strikes due to natural factors, and equipment blackouts due to maintenance of generators and transmission equipment. When frequency reduction is detected, the under-frequency load shedding (UFLS) scheme must release loads as an emergency control action to maintain and preserve system stability [3, 4]. Conventional UFLS schemes cannot ensure power system security and reliability, because the amount of load curtailments is predetermined and cannot be accurately estimated. This can be a disadvantage of conventional UFLS schemes, as improper load-shedding schemes can have catastrophic consequences.

To avoid an undesired frequency decline, the frequency must be detected so that corrective action can be taken properly. This paper proposes a defense scheme considering real and existing loads carried by IBT and the rate of frequency decline. The defense scheme will determine the amount of load to be released when a disturbance occurs. The main purpose of load shedding is to reduce the load in order that the frequency will achieve acceptable levels based on the grid code and prevent the power system fall into a worse situation. It is expected that the proposed scheme able to restore system stability after a large disturbance occurs. This research was conducted on the Java sub-electrical system with two IBTs disconnected.

2 Basic Consideration in Transient Phenomena of Power System

Power system operation for the dynamic load cannot be separated from transient phenomena. The ability of a power system to maintain synchronization when there is a large transient disturbance in a short period of time with major effects such as sudden loss of large loads, disconnection network, and short circuit is referred to as transient stability. Knowing transient phenomena will help determination of time for several pieces of equipment such as relays, and circuit breakers in specific conditions of power system operations which are related to voltage levels and transfer capacity among the system. The most critical condition for a power system to have the strongest withstand capacity is the condition of whether the system is back to stable after large disturbances during peak load [5].

The transient phenomena can occur as the load variant whether it is an increase of release. The dynamic load will affect the frequency. Frequency is an important parameter of the power system because it affects the entire interconnection network. Frequency is strongly influenced by the number of generations and consumer load. Load shedding occurs automatically or manually to protect generating units from potential blackouts [6]. If the amount of generating power is reduced too quickly, the frequency will fall. The governor and existing thermal power reserves do not help much, so in order to save and maintain the system from failure or damage to the power system, some load buses were released, so that the system load is reduced and the frequency can return to normal immediately.

A decrease in frequency caused by abnormal system conditions that exceed tolerance limits will trip generating units, resulting in total blackouts. To avoid heavy power flows and the undesirable islanding effect in large systems, under-frequency load shedding relays (UFLS) should be installed throughout the system. UFLS can correct the system frequency quickly to the allowable frequency limit. When the frequency has passed its setting value, UFLS is typically used to release the load on the distribution side (feeder) with a predetermined number of allocations and locations for each stage of the release. The main goal of UFLS is to release an appropriate amount of load in order to quickly restore system frequency to its nominal value [7, 8].

3 Methodology

This research adopted a sub-electricity in Java, which has two generator units, 16 buses, and two inter-bus transformers connected to a 500 kV interconnection system. An electrical diagram of the Ngimbang subsystem is shown in Fig. 1. In this study, the proposed method is evaluated under specific conditions when there is interference in two IBTs Ngimbang, causing circuit breaker 7A1, 7A2 on the 150 kV side, circuit breaker 7B1 at 500 kV side open then preventing electricity from the 500 kV system from being transmitted to the 150 kV system. Consequently, the Ngimbang system operates under island operating conditions, which is supplied by two generating units in Tanjung Awar-Awar. When it became an island operation, the existing power supply from Tanjung Awar – Awar plant was insufficient to supply the current load, so the situation worsened. In order to avoid overloading the generator, UFLS works to release the load by a predetermined amount [9]. However, the load released is excessive, causing the frequency to rise until it reaches the setting of the generator's relay, which causes the Tanjung Awar generator to trip. Because there is no power supply, the Ngimbang 150 kV subsystem experiences a total blackout. So, this becomes the foundation for investigations to determine which load to release when a disturbance occurs.

The load is determined by considering the loading conditions on the IBT as well as the readiness of the distribution transformer. The amount of load carried by the IBT will

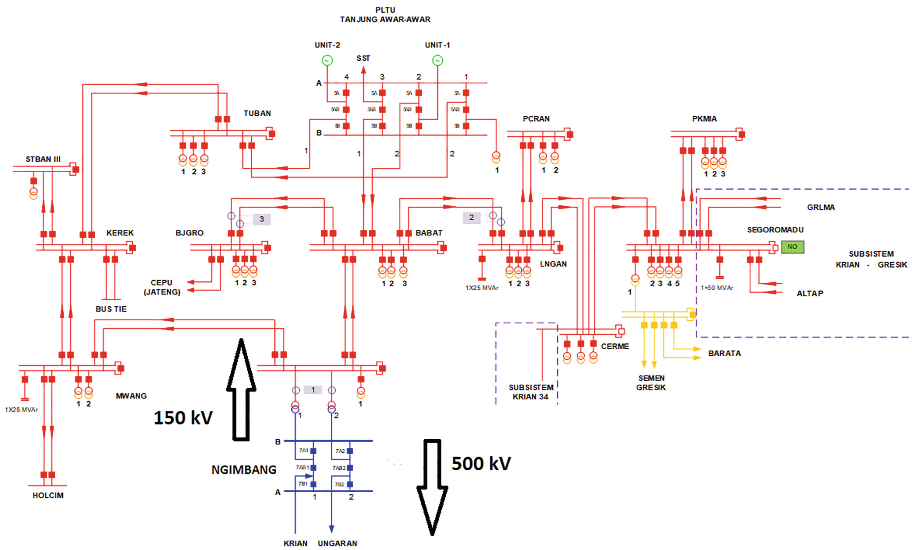


Fig. 1. Single line diagram Ngimbang subsystem

be used as a target for the amount of load to be released by the algorithm. As a result, the amount of load released by this method is precisely in accordance with the system's requirements. The proposed method is tested by power system software to simulate fault conditions that occur with the target load location that the algorithm has found while paying attention to the loading conditions on the IBT.

4 Result and Discussion

In this section, the performance of the conventional UFLS and the proposed defence scheme is investigated using the Java subsystem network. The Tanjung Awar - Awar power plant supplies 2 × 170 MW of power to the Ngimbang subsystem, which has a subsystem load of 544.56 MW. The disturbance is then simulated by releasing two IBT Ngimbang simultaneously in the first second. The simulation results will be compared to the conventional UFLS scheme and the proposed improvement defense scheme.

4.1 Existing Defense Scheme

Table 1 shows the UFLS settings for the Ngimbang subsystem's phases 1 through 7. The release targets of this UFLS relay are feeders and distribution transformers.

In the conventional UFLS scheme used in Indonesia, there are two types of UFLS: stage UFLS and island UFLS. When the system frequency detected 49.00 Hz–48.40 Hz, the UFLS stages release the load. While UFLS island work to release the load at a frequency of 48.30 Hz. Table 2 shows the load released during the island operation.

Based on Fig. 2a, when two Ngimbang IBTs are released simultaneously, the system frequency drops from 50 Hz to a critical level where the stage UFLS and UFLS island work to release the load in accordance with the predetermined target. The frequency increased significantly, causing the Tanjung Awar generator's relay to work to trip the generator. Due to the two units Tanjung Awar power plant being disconnected from the system, the subsystem experienced a total consumer blackout of 544.56 MW. Subsystem blackout at t = 11.85 s when the frequency reaches 51.5 Hz.

The comparison of the load subsystem Ngimbang and the power generation is shown in Fig. 2b. Where the generator provides 340 MW of power with a subsystem load of 544.56 MW from t = 0 s to t = 1 s, respectively. IBT Ngimbang is responsible for carrying the remaining load that the generator is unable to supply. When the disturbance occurs at t = 1 s, the system loses supply from IBT, resulting in a power outage and overload. In the graph, the governor had time to react quickly at t = 1.0015 s to increase generation power, but because the system lost a large amount of power in a short period of time, the governor was unable to restore the system to a stable condition permitted by Indonesian electricity network regulation [10]. The system slowly collapsed until a complete blackout occurred when the conventional UFLS scheme is used.

Table 1. UFLS setting stage

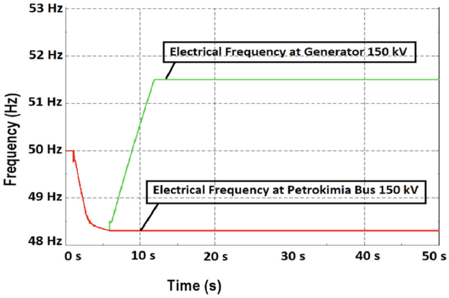
No	Phases	Freq	Bus	Trafo	Feeder/Load (MW)	Load Shedding %
1	1	49	Lamongan	1	Karang Geneng	37%
2	1	49	Lamongan	1	Turi	
3	1	49	Mliwang	1	Montong	69%
4	1	49	Mliwang	1	Kunduran	
5	2	48.9	Babat	1	Widang	21%
6	2	48.9	Bojonegoro	3	Kalitidu	9%
7	3	48.8	Mliwang	1	Temaji	27%
8	3	48.8	Mliwang	1	Bancar	
9	4	48.7	Tuban	2		
10	4	48.7	Babat	1		
11	4	48.7	Lamongan	2		
12	4	48.7	Lamongan	3		
13	5	48.6	Bojonegoro	3		
14	5	48.6	Ngimbang	1		
15	6	48.5	Tuban	3		
16	6	48.5	Petrokimia	Bus Tie	Bus Tie Petrokimia	
17	6	48.5	Cerme	3		
18	7	48.4	Bojonegoro	1		

Table 2. UFLS island

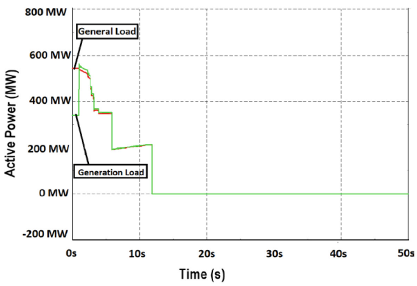
No	Phases	Freq	Bus	Trafo	Load
1	1	48.3	Bojonegoro	-	Bay Cepu Jateng 1,2
2	1	48.3	Babat	2	Trafo Distribusi
3	1	48.3	Babat	-	Bay Babat-Lamongan 1,2
4	1	48.3	Ngimbang	-	IBT Ngimbang 1,2
5	2	48.2	Babat	-	Bay Babat-Bojonegoro 1,2

4.2 Improvement Defense Scheme

In this section, the result of the improved defense scheme will be explained using the previously described case studies. The Ngimbang 150 kV subsystem is assumed to have a load of 544.56 MW and generate power of 2 × 170 MW. In the pre-disruption condition, IBT has a power of 216.1 MW, which will be used as a target value to determine the location of the load to be released. Based on the proposed improvement defense scheme, the list of load locations that must be released when two IBTs Ngimbang disturbance



(a)



(b)

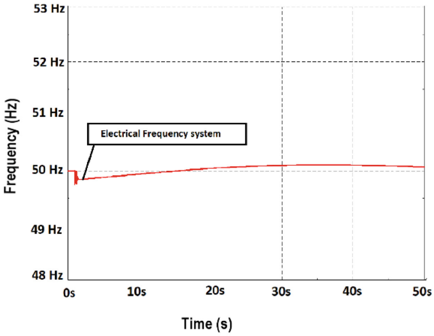
Fig. 2. (a) system frequency during contingency simulation with 2 IBTs Ngimbang released simultaneously (b) a comparison of the number of generators and loads with conventional UFLS after a disturbance

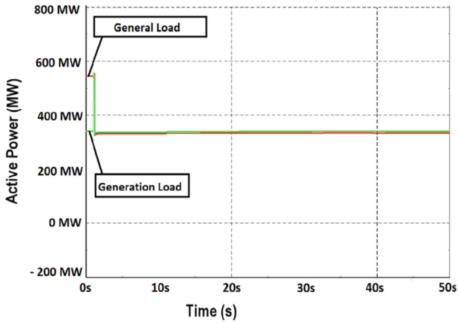
occurs is shown in Table 3. The total load released is exactly 216.1 MW in accordance with the target that must be released.

The disturbances occurred at Ngimbang IBT at t = 1 s, and corrective action was taken by releasing the load target determined in Table 3 at t = 1.2 s, in accordance with Indonesian electricity network regulation (grid code) [10]. The response of the system frequency after releasing the load is shown in Fig. 3a. The frequency shows better results; from t = 0 s to t = 1.0035 s, the frequency remains stable at 50 Hz, then begins to decrease at t = 1.0065 s to 49.84 Hz as a response to overload. And at t = 1.2015 s the system

Table 3. Location of load shedding with proposed defense scheme method

No	Lokasi	Enable	Priority	MW
1	4TUBAN5_TD1	ON	2	8,2
2	4SGMDU5_TD2	ON	2	31,68
3	4BJGRO5_TD3	ON	2	28,13
4	4BJGRO5_TD2	ON	3	20,65
5	4LNGAN5_TD3	ON	3	14,96
6	4PKMIA5_TD1	ON	3	11,03
7	4PCRAN5_TD2	ON	5	14,9
8	4TAWAR5_TD1	ON	5	4,21
9	4BABAT5_TD3	ON	5	18,59
10	4PKMIA5_TD3	ON	5	14,13
11	4NGBG5_TD1	ON	5	6,07
12	4TUBAN5_TD2	ON	5	12,97
13	4BJGRO5_TD1	ON	5	15,32
14	4PKMIA5_TDKT	ON	7	15,26





(a) (b)

Fig. 3. (a) System frequency during contingency simulation with 2 IBTs Ngimbang released simultaneously (b) a comparison of the number of generators and loads with improved defense scheme after a disturbance

provides a frequency response of 48 Hz after load shedding is performed. At t = 36 s, the system frequency rises to 50.096 Hz and then oscillates at 50.06 Hz until t = 50 s.

Figure 3b shows that the comparison between general load and general load remains stable from the initial conditions from t = 0 s to t = 1 s, but at t = 1.0015 s the generation load has increased by 562.1177 MW, and the general load recorded at 544.1765 MW. Then it gradually decreases until the improved defense scheme is executed to release the target load at t = 1.2 s, resulting in a decrease in the Ngimbang general load to 324.2269 MW and generation load to 328.6899 MW at t = 1.2015 s. The active power has a significant impact on the frequency stability system.

5 Conclusion

The system frequency is highly dependent on the active power profile and generating power system. Based on the simulation analysis performed on the specified case studies, it is known that the improvement defense scheme can save the system from unstable conditions that cause blackouts. The proposed scheme can also precisely determine the amount of load shedding required. In conventional UFLS, the system loses a load of 544.56 MW, resulting in a 150 kV blackout of the Ngimbang system. By implementing the improvement defense scheme, the exact load released is only 216.1 MW. This proves that the proposed scheme is more effective and can improve the conventional UFLS scheme.

Acknowledgements. We would like to thank the Faculty of Engineering, Electrical Department Diponegoro University for being awarded Strategic Grant Research 2022. We also thank PT PLN (PERSERO) for the data research and contribution during the preparation of the UFLS design.

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