Interconnection of Hydro Power Plant through 20 kV Distributed Line to Improve Electrical Power Supply in Dieng Central Java

Mochammad Facta[1], Hermawan[1]
[1]Electrical Engineering Dept., Universitas Diponegoro
Semarang – Indonesia
facta@elektro.undip.ac.id

***Abstract*— Hydro power plant is possible to be present and has interconnection to distribution line. The presence of such power plant is expected to supply additional power and overcome voltage drop at load side. In this paper, several experimental works based on simulation and primary data from field measurement are presented to show the performance of interconnection of hydro power plant through 20 kV distribution line to improve electrical power supply in Dieng – Central Java. Several requirements were observe and investigated by conducting simulation experiment. Several analyses such as Load flow, short circuit and stability were performed. As the results, the presence of hydro power plant has given positive impact to the profile of voltage in 20 kV distribution system. All power flows to the load properly and no reverse power back to the power plant or substation.**

Keywords*— *hydro power plant, load flow, shirt circuit, stability, distribution system.

I. INTRODUCTION

Dieng – Central Java, an area rich with mountain and beautiful views, is potential region for eco tourism and agriculture development. Electricity is nevertheless cannot be separated as vital key to develop Dieng as one of destination in tourism and agro industries.

Electrical supply for Dieng is fed by one substation equipped with 16 MVA Power Transformer. Most of load type is residential and home agriculture industry that can be categorized as static load. As the load increased to maximum, it was recorded that the minimum voltage at 20 kV distribution line was close to 19, 5 kV or below 5% of permitted voltage standard [1]. The power transformer at Dieng Substation has to accept 14,2 MVA of load and it means that the transformer already has burdened up to 88,5% from maximum capacity. Such voltage profile and transformer loading were undesired condition and it must be avoid in electrical power distribution operation because it will reduce the lifetime of transformer. Loading will be increase in the future and minimum voltage will be lower.

About 15 km away from Dieng substation, there is a Merawu river, which has potential energy to be harvested. Flow rate of water in the river is 15.42 m^3/second and it is possible to provide 7,785 kW or almost 8 MW potential electrical energy generated by micro hydro power plant. The power generated by micro hydro power plant then is possible to be interconnected to 20 kV distribution line dragged from Dieng sub station. The proposed scenario above is expected to reduce the transformer load at Dieng Substation and improve the voltage in 20 kV distribution line.

II. CONDITION BEFORE HYDRO POWER PLANT CONNECTED

Fig. 1 shows the result of load flow applied to Dieng Substation and surrounding network before the present of Hydro Power Plant (HPP). Voltage profile at the proposed interconnection point was 19.475 kV and the adjacent buses i.e. Bus C and D had magnitude voltage 19,503 kV and 19,567 kV consecutively. Main transformer 16 MVA at Dieng Substation at maximum loading had to 301 Ampere for Feeder Dieng – 02 and 108 Ampere for other feeders. Total load at main transformer was 14,169 MVA (11,319MW and 8,524 MVar) or 88,5% from maximum capacity of he transformer. Transformer was already burdened more than 80% and it results in reducing the lifetime. Voltage profile will be decreased in the future as the load increase.

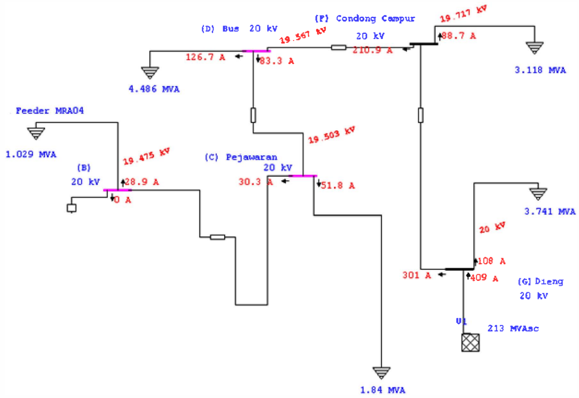

Fig. 1 Voltage Profile at Maximum Load before HPP installed

III. SIMULATION RESULT FOR PREPARATION STUDY BEFORE HYDRO POWER PLANT INSTALLED.

Following the requirement of the board of electrical state company, then a feasibility studies must be carried out before HPP installed and connected to the grid in 20 kV distribution line. The required studies are eligible to be obtained by conducting software simulation and calculation for several items below [2-5]:

a. Voltage profile after HPP installed and connected
b. Short circuit current at interconnection point and substation
c. Withstand and breaking capacity of existing interrupting current i.e. circuit breaker
d. Coordination among protective device i.e. over current relay.
e. Generator stability at possible highest fault due to short circuit.

The HPP is proposed to have two generators with 4.2 MW for each generators. Two-step up transformers 5.25 MW are designed to converse the voltage 6.3kV from generator to 20 kV line to line. At point B, electrical power from HPP is interconnected with 20 kV distribution line by using AAAC conductor with diameter 150 mm^2 and current ampacity up to 450 Ampere.

Fig.2 shows the voltage profile when the HPP is installed and connected to the grid. Voltage at interconnection point (B) increase from 19.475 kV to 19.88 kV. Voltage is recovered and it becomes 99.41 % from the nominal voltage 20 kV. At point C and D, which are close to the load, their voltage becomes 19.794 kV and 19.764 kV. The main transformer at Dieng substation gets reduced load due to addition electrical power from HPP. Total load of main transformer at Dieng substation becomes 230.3 Ampere or 7.978 MVA (7.662 MW and 2.222 MVar). This total load is equivalent to 49.86% from maximum capacity of transformer. The lifetime of transformer can be longer. The current flow from HPP to point B is 108.4 Ampere and it is below the maximum capacity of installed conductors. It is also found that there is no reverse power back to the HPP. or Dieng substation. It ca be summarized that the electric power is possible to be deliver to the load properly.

Fig. 3 shows the voltage profile at light load after the present of HPP. It is found that the use of load tap changer at HPP transformers has successfully adjusted the voltage at interconnection point from 20.188kV to 19.964 kV. The voltage at point C and D also become 19.929kV and 19.933 kV. There is no over voltage when the total load is minimum. It is also found that in this case there is no reverse power back to the HPP or Dieng substation

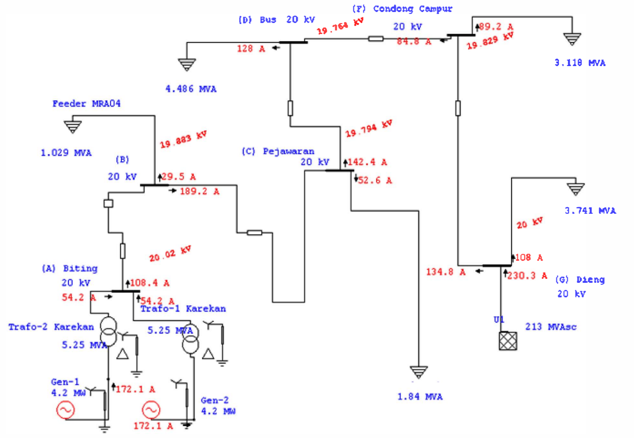

Fig. 2 Voltage Profile at Maximum Load after HPP connected

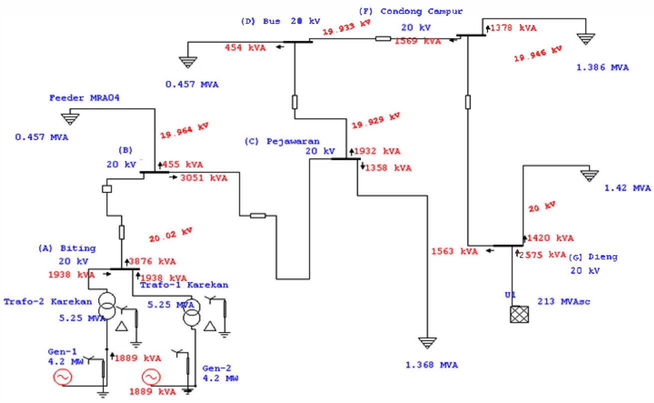

Fig. 3 Voltage Profile at Minimum Load after HPP connected

Fig. 4 and 5 shows the map of short circuit current when it is assumed that there is a three phases fault at interconnection point (B) and main bus at Dieng substation (G).

The maximum short circuit current at point B is 6.97 kA. This current fault is supplied from point A (Biting) 3.82 kA and point C (Pejawaran) 3.7 kA. Due to this fault, then the voltage at point A becomes 4.88 kV and voltage at Dieng substation becomes 17.03 kV. The existing Circuit Breaker has capacity of 12.5 kA, so the current faults is possible to be eliminate by existing circuit breaker.

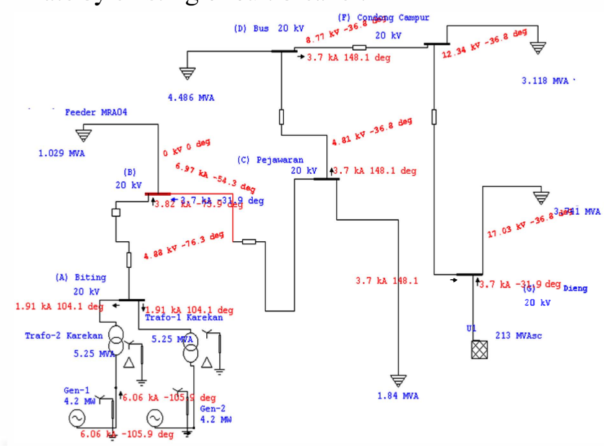

Fig. 4 Short circuit map when fault at interconnection or point B

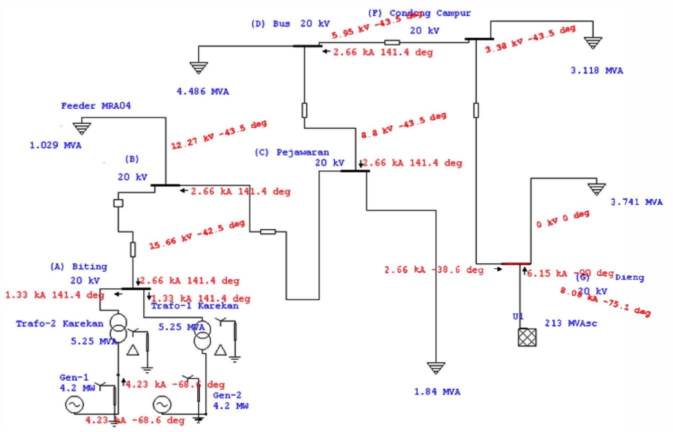

Fig. 5 Short circuit map when fault at Dieng Substation

The main protection at HPP is proposed to be overcome by over current relay and circuit breaker at switchyard in HPP location. There is additional recloser as protection device to protect the line B – C and it is coded at Recloser-2. Setting of current at Recloser-2 is expected to protect the conductor AAAC 240 mm^2 with 500 Ampere as its maximum current Ampacity. The setting for Rcloser-2 is 300 Ampere with inverse characteristics. Before the presence of HPP, there is overcurrent relay at Dieng substation and Recloser-1 at line D-C. The locations of protection device in the system are illustrated in Fig. 6.

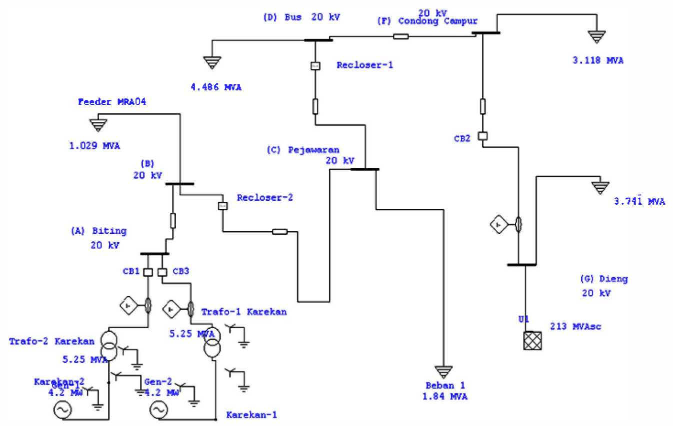

Fig. 6 Location of Protection Devices

Based on load flow study, current flows through current transformer (CT) and over current relay (OCR) at Feeder Dieng – 02 is 134,8 Ampere. Load current flows through Recloser-1 and Recloser-2 is 142.4 Ampere and 189.2 Ampere consecutively. Based on the current flow above then the setting and coordination of protection among OCR, Reloser-1, Recloser-2 are illustrated in Fig. 7. It is found that at normal condition no relay will be activated. Recloser will be tripped as current fault above 300 Ampere and the OCR will be also tripped when the fault current is above 500 Ampere.

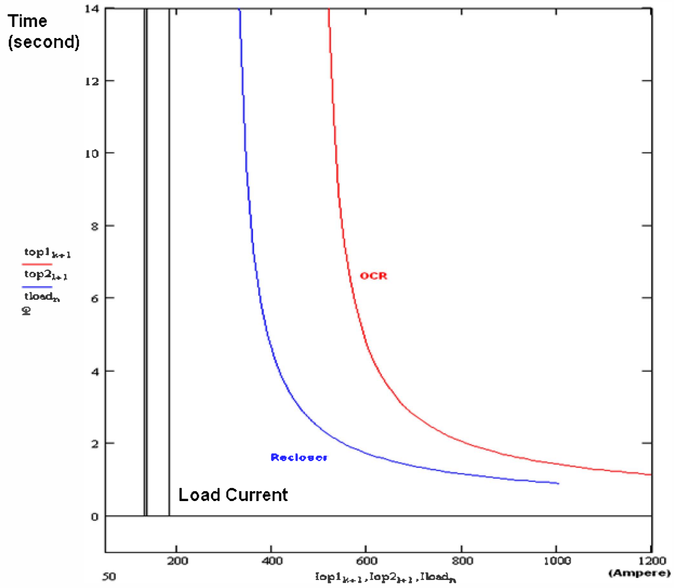

Fig. 7 Setting and coordination of Recloser and OCR

Fig. 8 gives illustration of simulated circuit to know the stability of generator at HPP when there is a fault at out going terminal of transformer at HPP. The simulation represents close fault at HPP. Three phases temporary fault is applied during the experiment b y using Matlab [6].

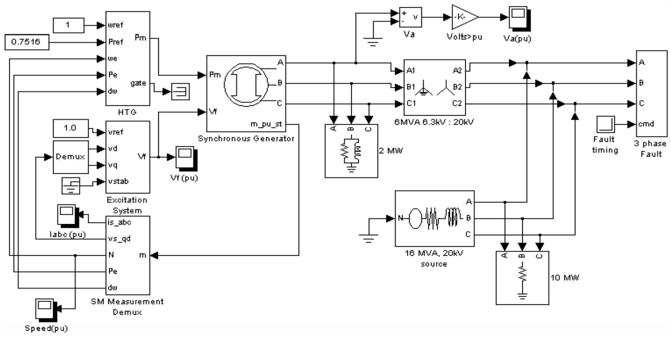

Fig. 8 Simulation circuit as fault occur at out going of HPP

Fig. 9 shows simulation results of terminal generator as three phases temporary fault occur at terminal of transformer at 20 kV side in per unit value. Fault occurs at 5 second and it is cleared at 5.2 second. Voltage at secondary of transformer at HPP has trend to be stable 1.2 second.

Fig. 10 shows speed responds of generator during temporary faults. Speed also represents frequency of the system. It is found that oscillation occurs after fault was removed. How ever, the speed and frequency is able to back in to stable condition after 1.2 second. The speed of generator is back in to its setting point. This evidence can be indicated that the generator is stable after temporary disturbance [7].

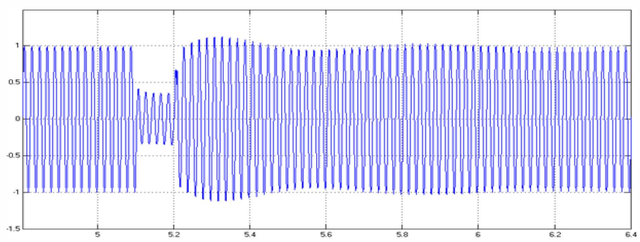

Fig. 9 Result for terminal voltage as fault occur at out going of HPP

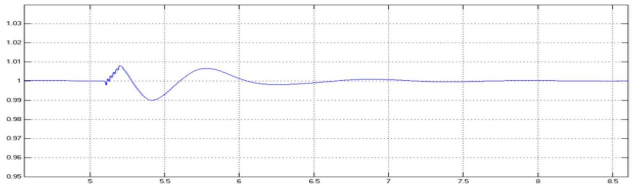

Fig. 10 Simulation circuit as fault occur at out going of HPP

The electric performance of interconnection system between HPP and distribution line from Dieng substation was presented. All power flows to the load properly and no reverse power back to the power plant or substation. The presence of HPP has given positive impact to the profile of voltage in 20 kV distribution system especially at Feeder Dieng-02. All potential fault current was examined, and the interrupting device installed are possible to work properly due to the magnitude of faults are still below the capacity of circuit breaker. The coordination among Reclosers and OCRs was carried out. At Normal condition no protective device is tripped. Based on short circuit map, current fault will be higher and most of them are in kilo Ampere. Such current value will make the protection device ensured to trip.

IV. Conclusion

Based on the experimental result carried out by using simulation several conclusions can be summarized as follow:

1. The presence of HPP gives positive impact to the profile of voltage at Feeder Dieng – 2. Improvement in voltage at 20 kV distribution line will affect the quality of low voltage at consumers' side.
2. Based on power flow analysis, all the powers produced by HPP and supplied by Dieng Substation are successfully sunk to the load. No reverse power occurs.
3. The presence of two generators and two transformers at HPP has increased the value of short circuit current during fault. However, the existing protective devices are able to interrupt the fault according their capacity.
4. The stability of two identical generators are considered good as the temporary fault removed to the system then the voltage, speed and frequency of generators are able back to normal setting value.

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