MITIGATION VOLTAGE SAG USING DVR WITH HYSTERESIS-ANN CONTROL ON DISTRIBUTION SYSTEM PUJON FEEDER LINE

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ABSTRACT

The paper talks about the mitigation of sag voltage on distribution systems. Sag Voltage often happens because of a short circuit fault 1 phase to ground. The fault has a huge impact on load breakage in the feeder of the Pujon line. Sag Voltage will be mitigated by utilizing Dynamic Voltage Restorer (DVR). DVR is one kind of custom device that is effective in overcoming sag voltage. DVR requires control in regulating voltage recovery on the Pujon line. This research proposes DVR control using Hysteresis combined with ANN to mitigate sag voltage on the line Pujon. A simulated test indicates that the improved control of Hysteresis with ANN can restore the load voltage in phase R on the mean of 97% resulting from the sags voltage on the Pujon extension line.

***Keywords**: Voltage Sag, DVR, Single line-to-ground, Hysteresis Control, ANN Control.*

I. INTRODUCTION

This research discusses the mitigation of sagging voltages in distributed supply systems. Sag Voltage is a growing problem experienced daily in many distribution networks[1]. This voltage causes a short-term decrease in load voltage at all interconnections of the Substation Sengkaling distribution system[2], where Substation Sengkaling there is the Pujon feeder line which has a lot of industrial loads. Voltage drops render by low-voltage short-circuit faults often happen on the Pujon power line[3]. Abnormal circuit short disturbance causes malfunctions or losses to the loads in the Pujon repeater, so it is necessary to find a better solution to protect the loading voltage from remaining in normal condition by using voltage compensations[4].

The compensation voltage could be obtained by wiring customized power tools to reduce disturbances to the load by adding voltage compensation using the Dynamic Voltage Restorer (DVR). DVR was chosen because it is the most effective over other custom power tools[5]. DVR performance depends on its controller to detect sag voltage and manage voltage compensation. A controller of both high speed and accuracy is required to compensate for a dip in voltage[6].

This research discusses the voltage sag caused by 1-phase to-ground circuit short disruption. A 1-phase to-ground circuit short disruption makes the load voltage decrease on an individual phase and affects the voltage line stability on the two remaining phases. Stress balance experiences a shift that makes the sag voltage on one phase and causes the other phase to be affected by the voltage drop. The voltage sag makes voltage compensation difficult to achieve because the drop magnitude voltage of the load line and the time of occurrence cannot be detected. Therefore, a control method using Hysteresis which is added an Artificial Neural Network (ANN) will be proposed to regulate load voltage compensation. Hysteresis control compensates the voltage by detecting the voltage changes that occur on the load[7]. However, the short circuit fault of 1 phase to the ground makes a slight voltage drop that occurs in the other two phases and has an impact on the hysteresis control error in compensating for the load voltage. Hysteresis control needs to be improved by adding ANN control to increase accuracy and proper voltage compensation. ANN serves to classify which phases need to be compensated and not. On the load line, there is a voltage threshold that needs to be compensated if there is a disturbance on the line so that other phases that do not experience disturbances do not require compensation because the load voltage is still acceptable. Improve Hysteresis with ANN in control DVR is supposed to compensate for the sag voltage condition caused by a 1-phase to-ground circuit short disruption.

II. RESEARCH METODOLOGY

A. *Sag voltage within the system*

Sag Voltage means the variation of the magnitude of the stress RMS with a level between 10% and 90% of the nominal voltage of the system and takes place over a period of 0.5 Cyclically to 1 time per minute[8]. Sag voltage can allow causing distribution system operation errors that are very sensitive to changes in voltage to customer load. Figure 1 illustrates the sag voltage for short circuit interference in the system. The model of a voltage divider

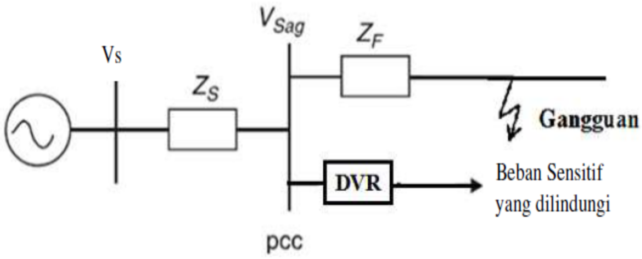

Figure. 1. Voltage Divider System.

system circuit is as follows.

Short-circuit interruptions occur on the distribution network line located at Z_F. The voltage divider circuit equation is used to determine the sag voltage imposed on the Points Common Couplings (PCCs) during an interruption process happen[9].

$$V_{sag} = \frac{Z_F}{Z_F+Z_S} V_S \quad (1)$$

Where V_{sag} represents the sag of voltage caused by a circuit short. V_S represents source voltage, Z_F is referred to as interference impedance and Z_S represents source impedance. So it can be formulated as follows.

$$Zs = R_s + jX_s \text{ and } Z_F = R_F + jX_F \quad (2)$$

The type of transformer connected to the load will give different changes in the amount of voltage at the voltage sag[10]. Voltage sag can be represented using functions based on the characteristics of the time the voltage sag occurs, namely as follows.

$$V(t) = \begin{cases} V_m \sin(\omega t) & if\ t < t_1 \\ V_{mSag} \sin(\omega t + \Phi) & if\ t_1 < t < t_2 \\ V_m \sin(\omega t) & if\ t > t_2 \end{cases} \quad (3)$$

Where V_m represents the peak voltage value before a disturbance occurs. ω representation the angular frequency, V_{mSag} is called the peak value of the voltage as long as the sag voltage, Φ represents the jump of phase angularity, t_1 called the first initialization time the voltage sag occurs and t_2 as the time the voltage recovers to normal conditions.

B. *Dynamic Voltage Restorer (DVR) wtihin the system*

DVR is part of one type of Customized Power tool device that has excellent capabilities compared to other Custom Power[11]. This device is very suitable for protecting sensitive loads against voltage drops over a short duration and a quick period of time. The DVR is a supervised stress supply that is placed between the supply side of the source and the critical load to be protected. This equipment serves to input voltage into a distribution network to compensate for disturbances voltage that occur and protect the load voltage. DVRs that are used to restore voltage or improve voltage on the load side and position are arranged in series with a distribution system to protect sensitive equipment against voltage sag.

Dynamic Voltage Restorer has a power circuit and control circuit. Control circuit or control circuit serves to regulate the parameters of the signal generated from the line system to be controlled so that it can be determined that the DVR must be injected into the system, where the signal includes: voltage, frequency, phase shift and others in the system. Based on the control signal obtained from the control circuit, the voltage needed to be injected through the power circuit will be generated.

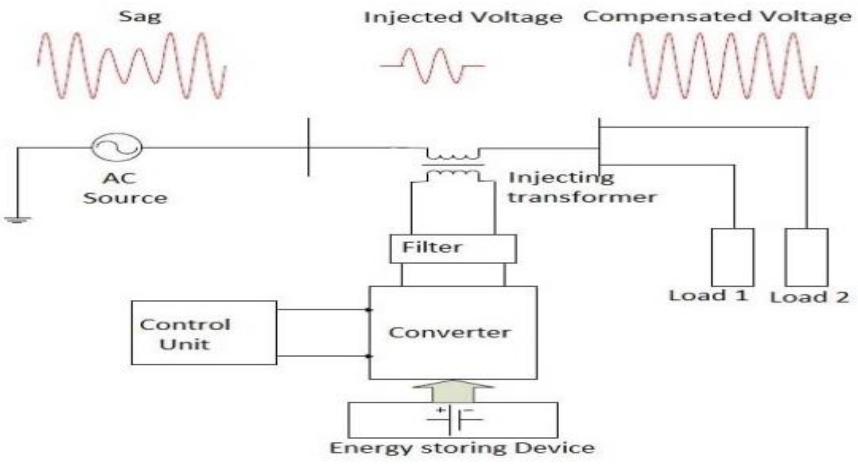

Figure. 2. Dynamic Voltage Restorer (DVR) Configuration System.

DVR has an array of components including a DC source, a Voltage Source Inverter (VSI) that uses a three phase inverter with IGBT, a control circuit, a low-pass filter, and a step-up transformer.

One of the DVR compensation techniques to overcome the sag voltage is using the pre-sag technique. The pre-sag strategy compensates for the gap between a sag voltage and a pre-sag voltage to provide continuous voltage storage under the same voltage phase and the same magnitude as that of the initial rating voltage[12].

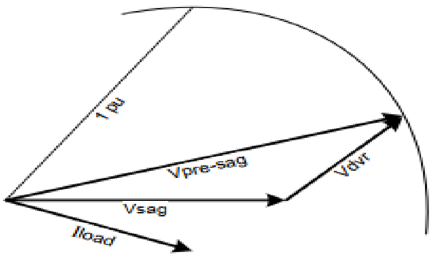

Figure. 3. Pre-Sag Compensation Technique.

Voltage-dvr (V_{dvr}) is an injection of voltages generated from DVR, where a voltage of DVR can be obtained from the following equation.

$$V_{Inj-DVR} = V_{pre-sag} - V_{sag} \quad (4)$$

DVR requires control of the compensation for sag voltage and sag time. So the Hysteresis improvement with the ANN method is offered to detect, control, and mitigate the sag voltage that occurs on distribution lines.

C. Hysteresis Control-ANN

Sag Voltage detection using Hysteresis control. Control of hysteresis is based on the error voltage generated by the difference in reference voltage (Vref) and actual voltage (VS). If it reaches the limits Band of Upper Hysteresis (UHB) or limit Band of Low Hysteresis (LHB). Then limit lower/upper band will trigger the DVR device to generate a compensation pulse voltage for load[7].

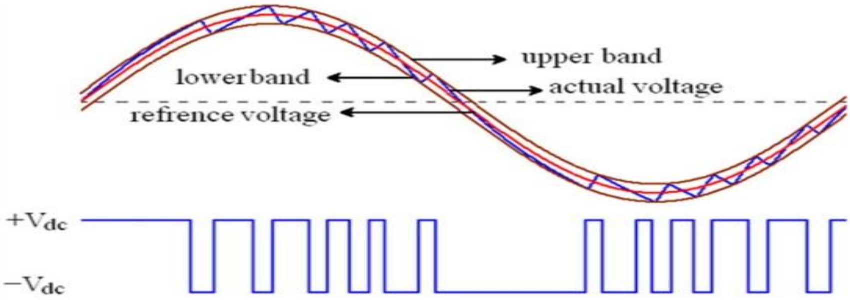

Figure. 4. UHB and LHB on Hysteresis Control.

The error voltage equation is obtained as follows.

$$e(t) = \frac{1}{2}V_{Load} - V_{Ref} \quad (5)$$

V_{Ref} is the reference voltage obtained from the following equation.

$$V_{Ref} = \frac{1}{2} V_S \quad (6)$$

Figure 5 shows a control Hysteresis unit diagrams on DVR.

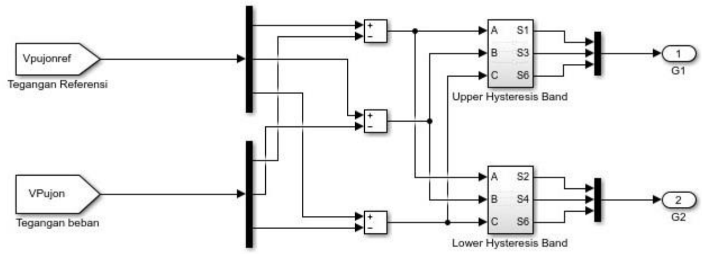

Figure. 5. Simulation control Hysteresis unit diagrams.

Hysteresis control uses a comparison between the load reference threshold and the actual stress load. Hysteresis control produces an output signal to the voltage inverter with a UHB limit of 1.35e-3 and LHB of -1.35e-3.

The voltage sag makes voltage compensation difficult to achieve because the magnitude and time of the load voltage decrease cannot be detected. In distribution networks, a single-phase short circuit to ground results in a voltage drop that occurs on the main phase and impacts the other two phases in the system. This has an impact on the hysteresis control error in compensating for the load voltage, in which the hysteresis control cannot compensate for the voltages in a balanced way from the three phases in the distribution line. The hysteresis control will be improved by adding ANN control to correct the existing compensation error and improve the accuracy with precise voltage compensation.

The hysteresis control is improved by adding ANN control to overcome the injection error, where ANN will be used to decide the load voltage compensation at the time of voltage sag in real-time which corresponds to the maximum voltage at each voltage sag of the hysteresis error. ANN was designed with a Levenberg-Marquardt (LM) training algorithm. The algorithm was chosen because it has a high degree of accuracy and accuracy, which makes the algorithm very efficient[13]. The error voltage measurement data from the hysteresis control was used for the ANN trial. System input and output target data consists of 20,000. Then the data process is divided into two subs. The first sub 70% of the sample is used to train ANN, and the second sub 30% is used to test and validate the system network. ANN performance is measured by calculating the mean-square error (MSE) in the equation (7).

$$e = \frac{1}{p} \sum_{i=1}^{p} \left\| y^{(i)} - v^{(i)} \right\|^2 \quad (7)$$

Where p represents the number of trial data inputs, y represents the ANN output vector, v is the desired output.

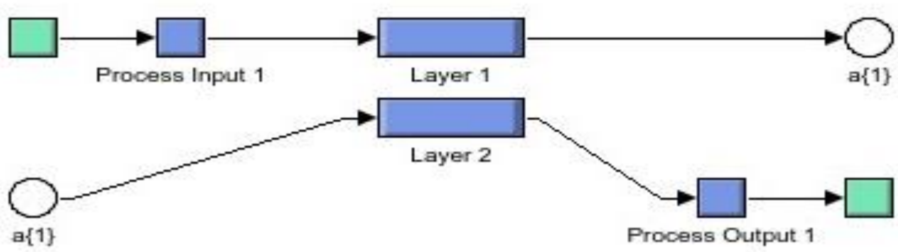

Figure. 6. Modeling Control ANN.

Figure 6 shows the simulation process using ANN control.

Figure 7 shows a block diagram of the MATLAB-Simulink Improved Hysteresis Control with ANN control on a DVR.

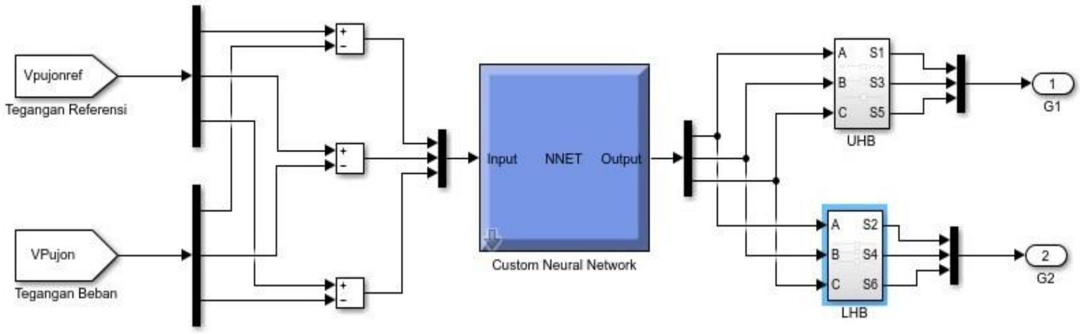

Figure. 7. Simulation Block diagram of Improves Hysteresis Control with ANN Control.

III. RESULT AND DISCUSSION

Simulation of a 1-phase short circuit to the ground applied to a distribution line of the Pujon branch.. Figure 8 shows the distribution system with DVR interference and compensation.

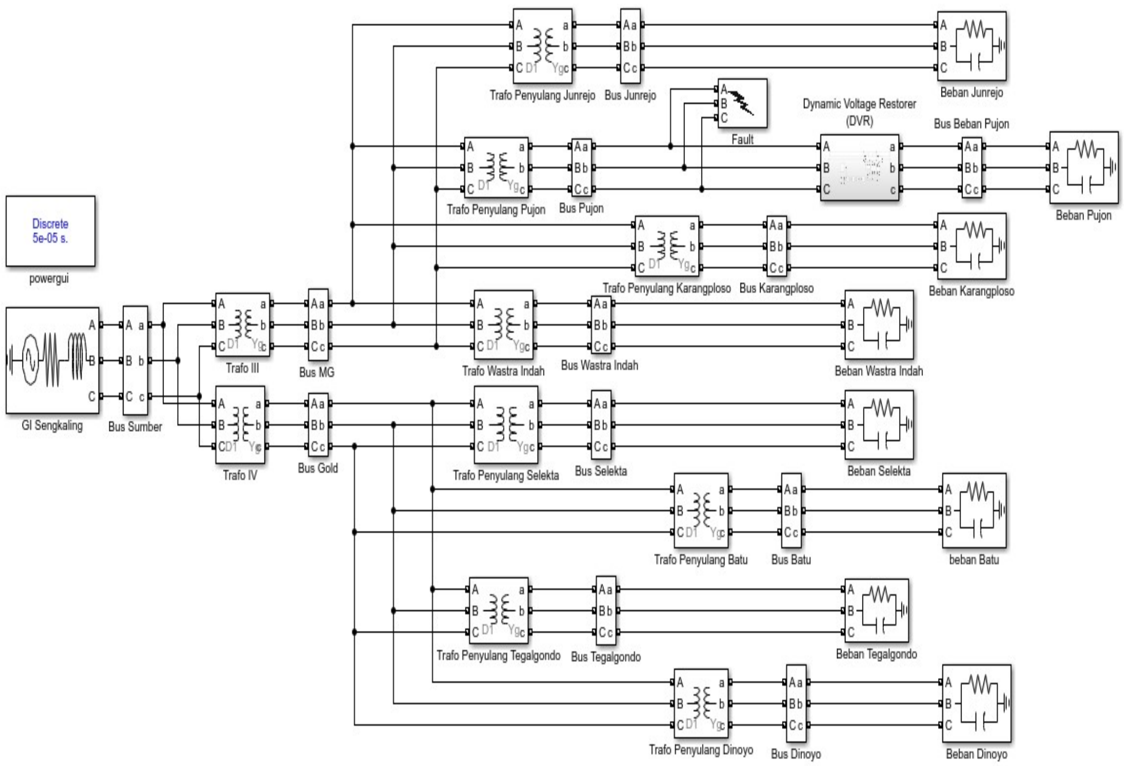

Figure. 8. Simulation of 1-phase short circuit to the ground interruption in GI Sengkaling Pujon Feeder Distribution System.

Simulation of GI Sengkaling distribution system experiences voltage sag on the Pujon feeder line. The DVR is installed on the Pujon load line as compensation for the load voltage. Then the load voltage is analyzed and validated.

A. Pujon Feeder Distribution System in Normal Condition

Pujon feeder distribution system when a condition without interference is applied to the system. Figure 9 shows the Pujon load voltage.

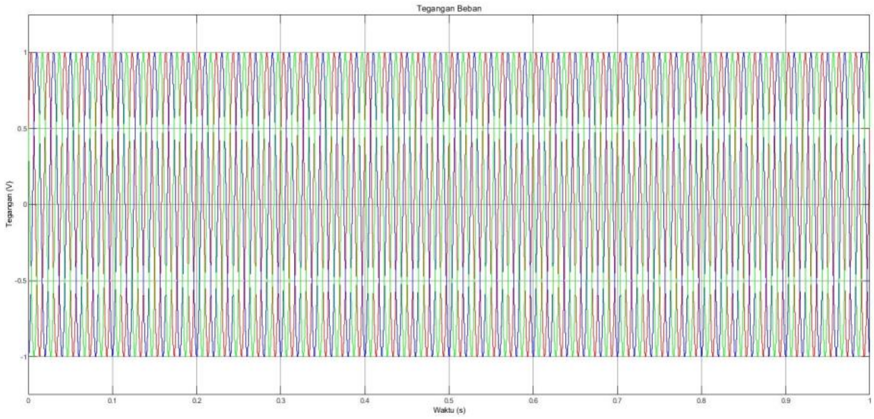

Figure. 9. The Voltage at the Pujon Feeder Load in Normal Conditions.

The distribution system of the Pujon repeater when conditions without disturbances in the system, where the loading stress is 1 pu under normal conditions.

B. Pujon Load before Having the DVR in Line Feeder with 1 phase to-Ground Circuit Short Disruption

Simulation of a 1-phase short-circuit failure to ground is applied to a channel in Pujon, where the value of interference impedance is 2.8 Ω and the time interval is 0.5 seconds. The fault is made between a period of 0.3 to

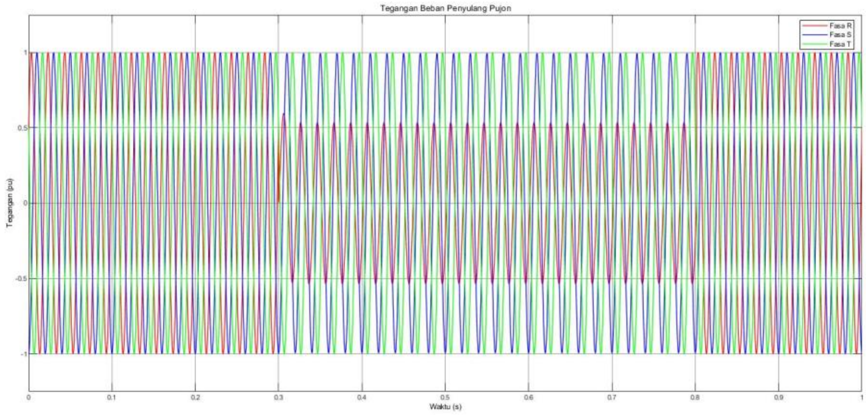

Figure. 10. Short Circuit Fault Applied to the Distribution System in Pujon Feeder Line.

0.8 seconds.

The simulation results show that the load has decreased in phase R by 50% and sag voltage by 0.53571 pu or 10741.2 volts. The decreased load voltage immediately causes damage to the customer's equipment in the Pujon Line extension, so handling is needed so that the customer's equipment is not damaged.

C. Pujon Load after the DVR Placed in Line Feeder with 1 phase to-Ground Circuit Short Disruption

Retrieved from figure 11 shows the simulation voltage load results of the DVR voltage compensation using the improved Hysteresis control with ANN.

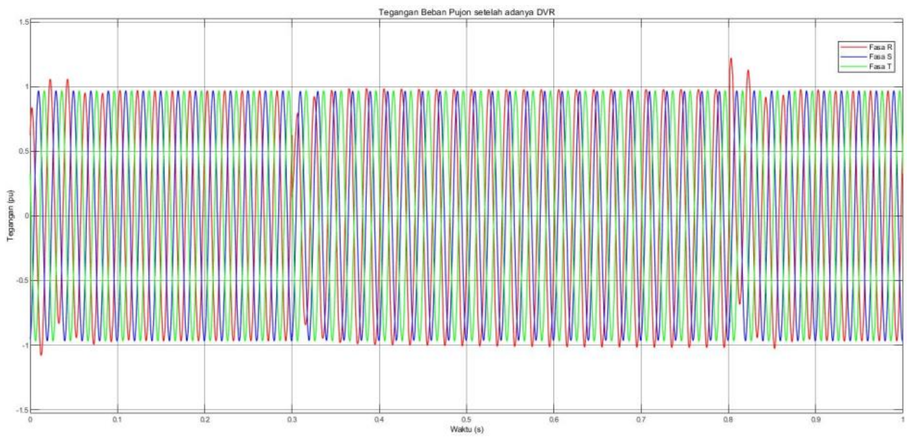

Figure. 11. Pujon Feeder Load after Compensated with a DVR.

DVR can compensate the load voltage on the Pujon extension line of 0.9682 pu or 19364 Volts in phase R with a voltage drop that occurs at a load of 50%. A stress compensation performed by DVR has a delay at the beginning and end of 0.05 seconds and stabilizes at 0.35 seconds so that it is still acceptable to the load on the Pujon repeater system.

D. Voltage Sag Analysis Before and After the DVR on the Load Side at Pujon Feeder Line

DVR voltage compensation uses Hysteresis control with ANN, where simulated there is a short circuit 1 phase to-ground in the Pujon extension line. The simulated fault occurs at a load Pujon extension line with a fault impedance of 2.8 Ω to 6.1 Ω. The voltage sag that results varies from 50% -80% in the Pujon extension line.

TABEL I
DVR VOLTAGE COMPENSATION BEFORE AND AFTER IN LOAD PUJON FEEDER LINE

Voltage sag In load	**Line Before DVR Compensated**			**Line After DVR Compensated**		
	R	***S***	***T***	***R***	***S***	***T***
50%	54%	100%	99%	96.8%	99.9%	99.5%
60%	61%	100%	99%	96.8%	99.9%	99.5%
70%	71%	99%	100%	97.2%	99.5%	100.0%
80%	80%	100%	100%	97.4%	99.6%	100.1%
Average	66%	100%	100%	97.0%	99.7%	99.8%

DVR using improved Hysteresis control with ANN produces an average voltage recovery at load R of 97%. Simulation outputs reveal that ANN-enhanced control in Hysteresis is effective in restoring the load voltage from a 1 phase to-ground circuit short disruption. Hysteresis control with ANN can properly control the compensation given by the DVR to the Pujon extension line so that it can keep the load voltage from a 1 phase to-ground fault which can cause damage to customer equipment.

IV. CONCLUSION

Analysis of voltage sags in the Pujon GI Sengkaling feeder distribution system can be compensated for by adding a DVR. DVRs are known as the most effective custom devices for dealing with voltage sags on distribution lines. A voltage drop simulation caused by a 1 phase to-Ground Circuit Short Disruption on a Pujon extension line is carried out. The circuit short interruptions have a very poor quality effect on the load in the Pujon repeater which results in damage to customer equipment, so it needs to be handled properly. DVR using improved Hysteresis Control with ANN is proposed to adjust the voltage compensation at the feeder load which is experiencing disturbances. Simulation outputs demonstrate that the DVR using ANN-enhanced Control Hysteresis is able to Compensation load voltage at phase R, which experiences an average voltage sag of 97% from the short circuit 1 phase to ground that occurs in the Pujon feeder line.

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