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Troubleshooting Generator Sets using Expert System

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Abstract
PT. Zaman Teknindo (PT. ZT) is a company engaged in Mechanical and Engineering field which is registered as one PT. Telkomsel vendors. The problems that occur at PT. ZT, if the power outage and generator set (generator) does not start automatically. The corrective team on duty at that time will go to the field and find a solution to the problem. With a lack of knowledge from the corrective team, they need help from the mechanical team. The mechanical team is an external team of PT. ZT. To bring a mechanical team requires an enormous cost and a relatively long time needed to get to the location. Based on the problem above, this study proposes a forward chaining expert system that is by depth-first search using the certainty factor method. To prove whether a fact is certain or not, it must be in the metric form in generator troubleshooting. The research methodology used the Software Development Life Cycle (SDLC) starting from problem identification, analysis, design, coding, testing and maintenance. This system is web-based, so users can easily access and choose symptoms of the damage. With this system makes it easy for PT. ZT especially the corrective team in the field can easily find out the damage symptoms without having to meet with experts directly.

Keywords: Expert System; Troubleshooting; Generator Set; Certainty Factor; Website.

1.0 INTRODUCTION

Generator Set or known as a generator is a machine that can convert mechanical energy into electrical energy (Bastari *et*. all). Although PT. ZT is a large company that has been established since 2009 with its address at Jalan Srikandi, Komplek Ruko Wadya Graha II, Blok B, No. 6-8 Pekanbaru, nonetheless PT. ZT has a problem in the field. The problem that arises is when a power outage occurs where the generator does not start automatically. Alarm detection from the generator will light continuously in a period of 5-10 minutes. Telkomsel on duty at the time gave orders to PT. ZT team to check. The team from PT. ZT will check the site consisting of a corrective team. The corrective team is a team that tries to look for problems that exist in the generator set, then fix it. Problems that often arise by the corrective team such as damage to generators and engines include Revolution Per Minute (RPM) engine drop, solenoid does not open, the engine unexpectedly dies, ammeters are not pointing and others. This problem certainly makes it difficult for the corrective team to handle it. With the lack of knowledge from the corrective team regarding the damage to the generator, the corrective team needs help from an expert mechanical team. The mechanical team is a team that is not in the organization of PT. ZT and this team have much higher knowledge compared to the corrective team. The mechanical team will go to the field to find a solution to the generator problem. To bring in a mechanical team certainly requires an enormous cost that must be paid by PT. ZT.

Based on the description above, of course, with manually resolving directly to the field certainly takes time, especially if the site to be visited is quite far or the corrective or mechanical team is not at the site when required. To overcome this problem, an expert system is necessary. With an expert system, it will be easier to do a checking and repair analysis on the generator set.

2.0 LITERATURE REVIEW

Expert System

Expert systems are systems that distribute human knowledge to a computer, made and designed by computers in various fields according to one's expertise. According to (Rich and Knight, 1994), the expertise can be in education form, medicine or fields related to the improvement of electronic equipment, especially generator sets. With this expert, the system is able to display and solve problems in real-time like an expert.

Certainty Factor

The expert system method that will be chosen is the Certainty Factor (CF) with the depth-first search. The selection of this CF method (Stephanie Halim, dan Seng Hansun 2015), can provide accurate results obtained from calculations based on the selected symptom weights and can provide answers to problems whose actuality is uncertain. Although the CF method is fairly long, this method is still used by researchers today in solving existing problems.

Forward Chaining

Forward chaining or runut strategy forward is a query that start the process of quest of a bunch of the data or fact, these words of the able to be searched and inference that becomes the solution of the problem faced by (Wibowo *et*. all).

Associated Research

Of associated research namely research formerly with link to this research, so that there is comparison or a source of more clear how this study made, comparison done to find which method is better applied to repair generator as been noted in Table 1.

Table 1. Associated Research

No.	Author	Title	Year	Method	Results
1	Nugroho, Eko Sutanto Bayu	Expert System Detect Damage to Generator Power	2011	**Backward Chaining**	Expert system can be used to help find solutions and types of damage to power generators quickly and precisely.
2	Irfan Sanusi, Bambang Trisno & Maman Somantri	Application Expert System of Diagnosing a Disorder Generator Set Over Load	2012	***Forward Chaining***	Application expert system of diagnosing a disorder generator set over load provide solusions to generator set over load quickly to the user.
3	Erwan Prastyo Wibowo	Applications Expert System For Diagnostics Damage BTS (Base Transceiver Stattion) at PT. Indosat. Tbk Kediri Using Method Forward Chaining	2017	***Forward Chaining***	• Method *forward chaining* in designing expert system for activities *troubleshooting* BTS. • Improve the efficiency of technician performance in activities *troubleshooting* BTS because it can be done quickly without having to ask

3.0 METHODOLOGY

The methodology for this research used the System Development Life Cycle (SDLC) methodology. SDLC is a collection of interrelated phases where the previous phase will produce activities for the next phase comprised of

Project Identification and Selection, Analysis, Analysis, Design, Coding, Testing and Maintenance as shown in Figure 1.

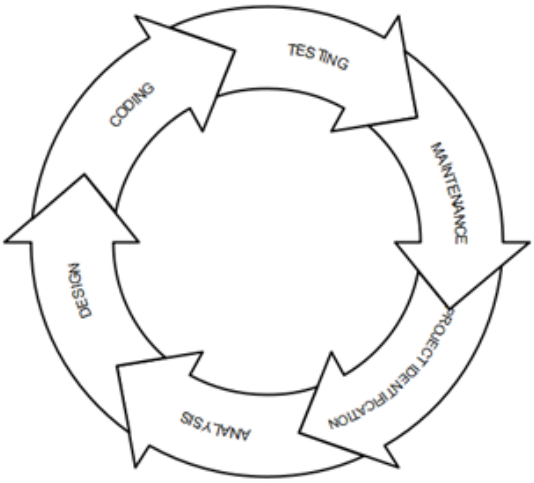

Figure 1. SDLC Phase Cycle

From these phases has the following roles and functions:

a. Project Identification
At this stage observations and interviews were conducted directly with the mechanics and the field team regarding the damage to the generator set. In the process of identification and selection obtained problems exist in the generator set, such as damage to generators and engines including Revolutions Per Minutes, Engine suddenly dies, Amperemeter do not point and others.

b. Analysis
In the second stage, which is carrying out an analysis process such as software and hardware requirements in the implementation process. It required hardware as listed below:

1. Hardware Device
   - Server computer specifications : Intel(R) Core(TM) i3-2100, 4 GB RAM, and 320GB Harddisk Drive (HDD)
   - Client Computer : Intel(R) Core(TM) i3-2100, 2 GB RAM, and 160GB Harddisk Drive (HDD)
2. Software Tools
   - OS Windows XP/7
   - Notepad++7.5.8
   - Xampp control panel 5.5.27-0-VC11
   - Pingendo

Then to conduct the analysis also in the form of a manual calculation of solving generator set using certainty factor.

c. Design
The design of in this system is similiar to creating a Graphical User Interface (GUI), use case diagrams, activity diagrasm, class diagrams, state diagrams, sequence diagrams, component diagrams.

d. Coding
After the design process is complete, the next step is making coding scripts. The programming language used is PHP framework codeigniter and XAMPP database creation.

e. Testing
At this stage testing includes :
   - Repairing and testing of the system from indication of defects, bugs, errors and so on in the future that will be used by the user.
   - Database creation in accordance with the concept and design scheme.
   - Responsible and guarantee the new system can run optimally, effectively and efficiently.

f. Maintenance
In the maintenance stage must be carried out after the program is declared running and is appropriate for later use, namely preserving and maintaining the program regularly so that it can be used optimally, effectively and efficiently, i.e. by updating when there is the latest information.

3.0 RESULTS AND DISCUSSION

Use the New Case Diagram

Use Case Diagrams illustrate a sequence of interactions between one actor and another in a system. In designing this knowledge system has two actors who play the role, namely admin and user. The admin role is inputting a knowledge base. This system will later give questions about the damage that occurs to the generator set and provide a report on the diagnosis of the damage along with a solution. The consultation process is carried out using a knowledgebase and the symptoms of generator damage that are already available as described in Figure 2.

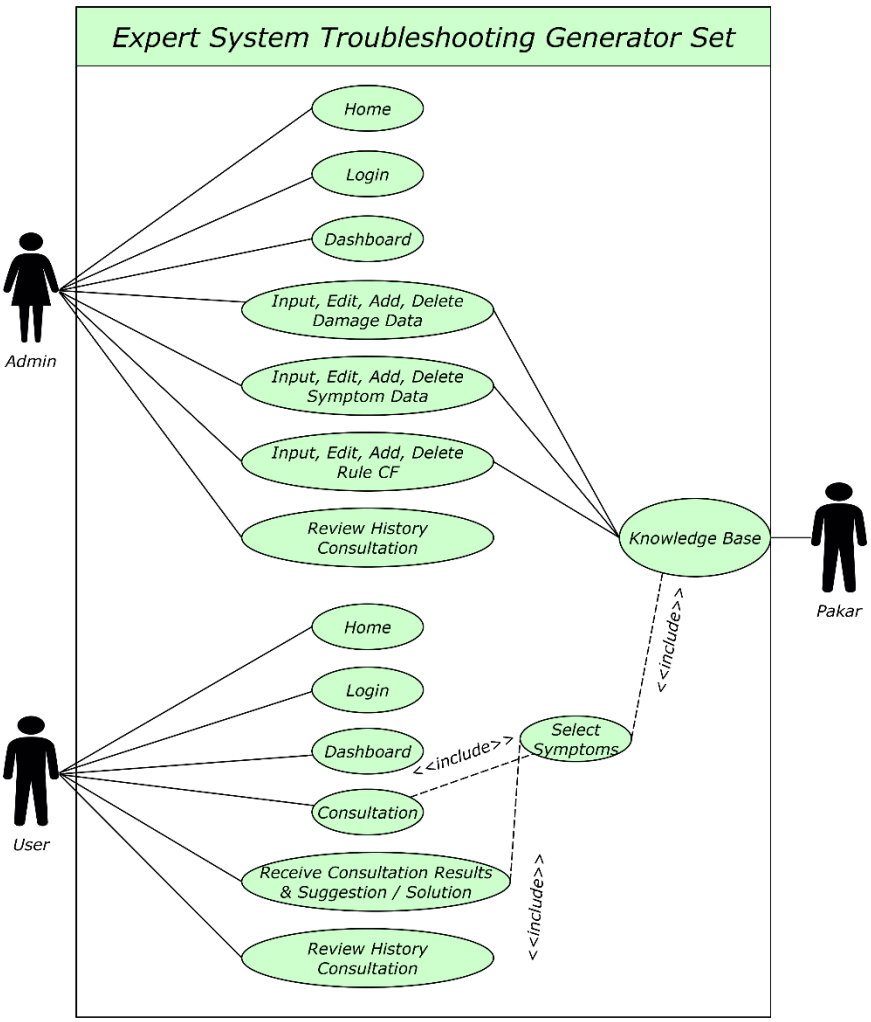

Figure 2. Use Case Diagram of a Newly Designed System

Activity New Diagram

Activity Diagram illustrates the various activity paths in the system that are designed as showed in Figure 3 which are the new activity flow for the admin and Figure 4 the new activity for the user.

Class Diagram

Figure 5 illustrates a new class diagram that displays the attributes or conditions of a system and the relationships that are connected therein interconnected with one another.

State Diagram

In Figure 6 and Figure 7 elucidate the flow diagram state admin and user on the login system in expert system application troubleshooting generator. The flow process when the user is logged in, the system will display a

username and password. The system will verify the data in the database. If the login is successful, the user is directed to the dashboard page, but if the login fails, repeat the login process.

Sequence Diagram

In Figure 8 and Figure 9 elucidate the flow diagram state admin and user on the login system in expert system application troubleshooting generator. The flow process when the user is logged in, the system will display a username and password. The system will verify the data in the database. If the login is successful, the user is directed to the dashboard page, but if the login fails, repeat the login process.

Component Diagram

The system component diagram explains the information system about the use of resources on a system designed as described in Figure 10 In this information system design, using the Windows Operating System that provides resources for MySQL as a database server and resources for a browser application for Framework Code Igniter (CI). The CI Framework provides its services for the use of the PHP programming language, then the system is run using a browser application.

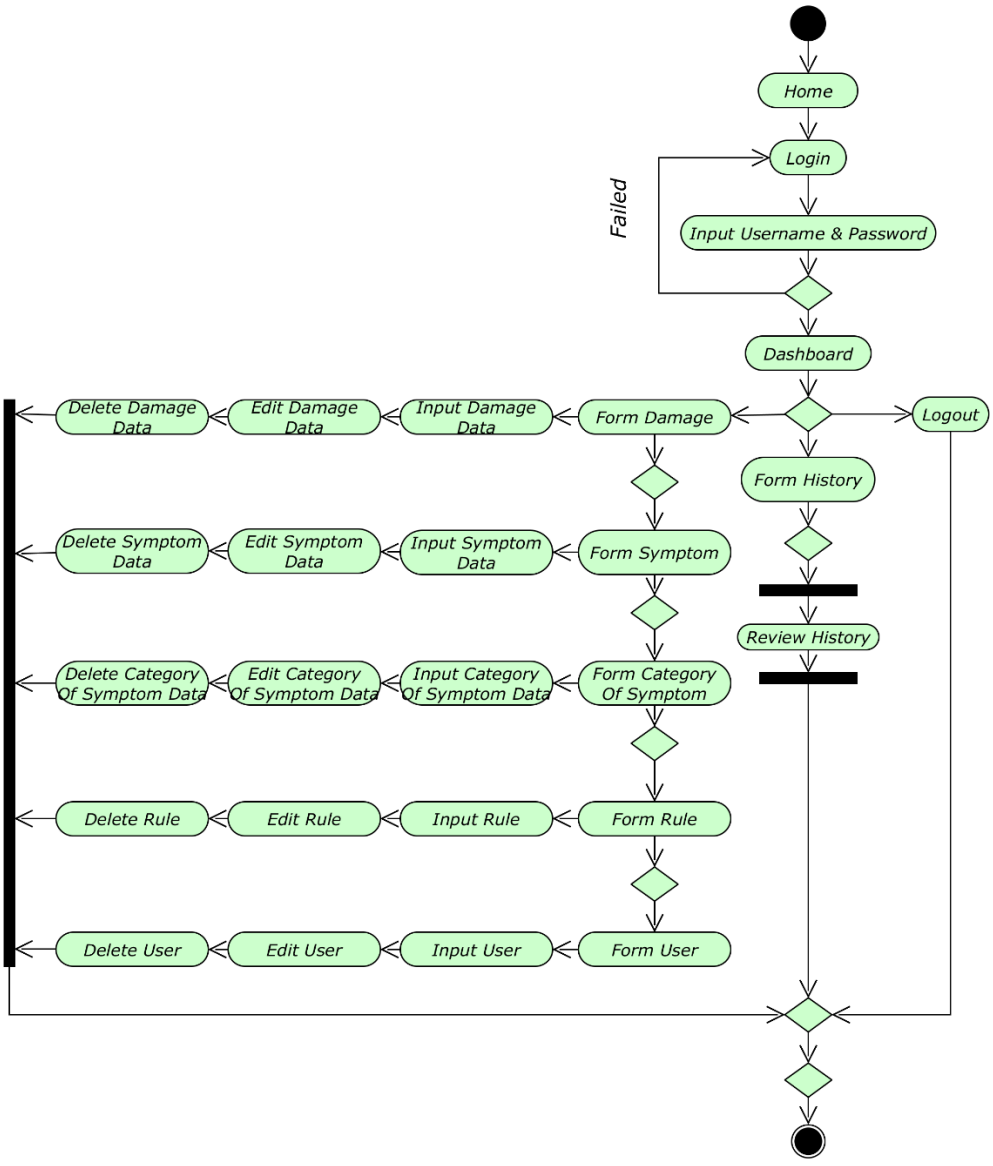

Figure 3. Activity Diagram Admin

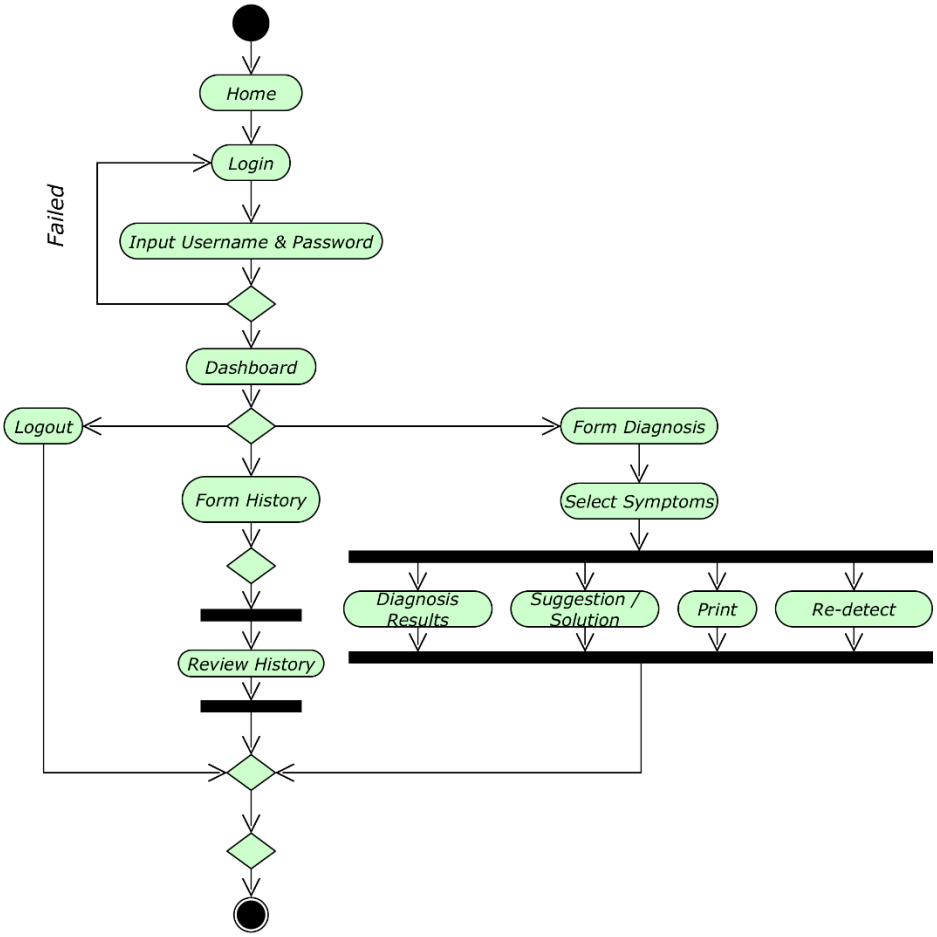

Figure 4. Activity Diagram User

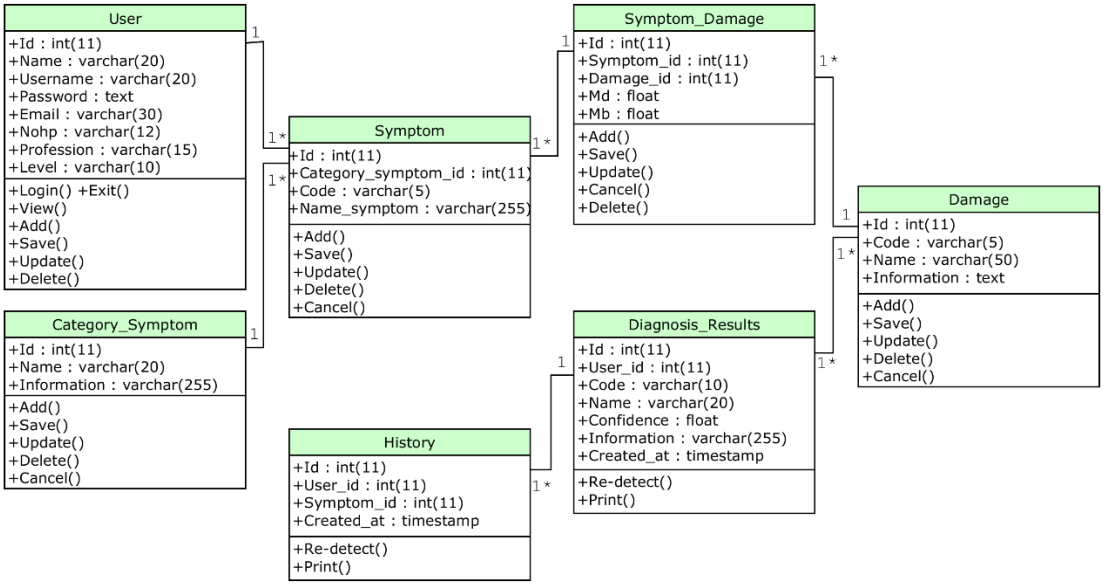

Figure 5. Class Diagram

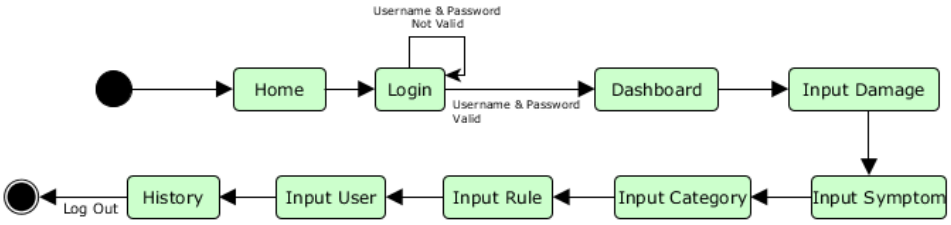

Figure 6. State Diagram Admin

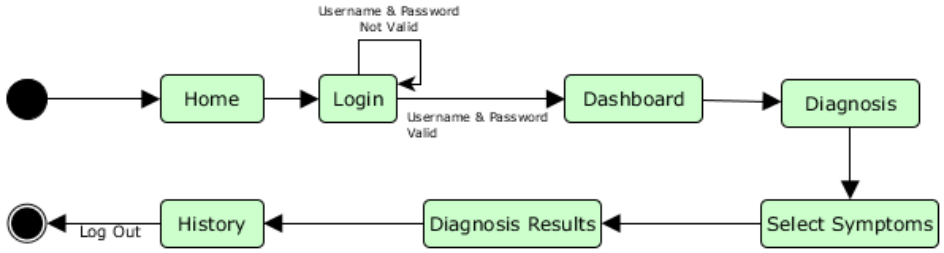

Figure 7. State Diagram User

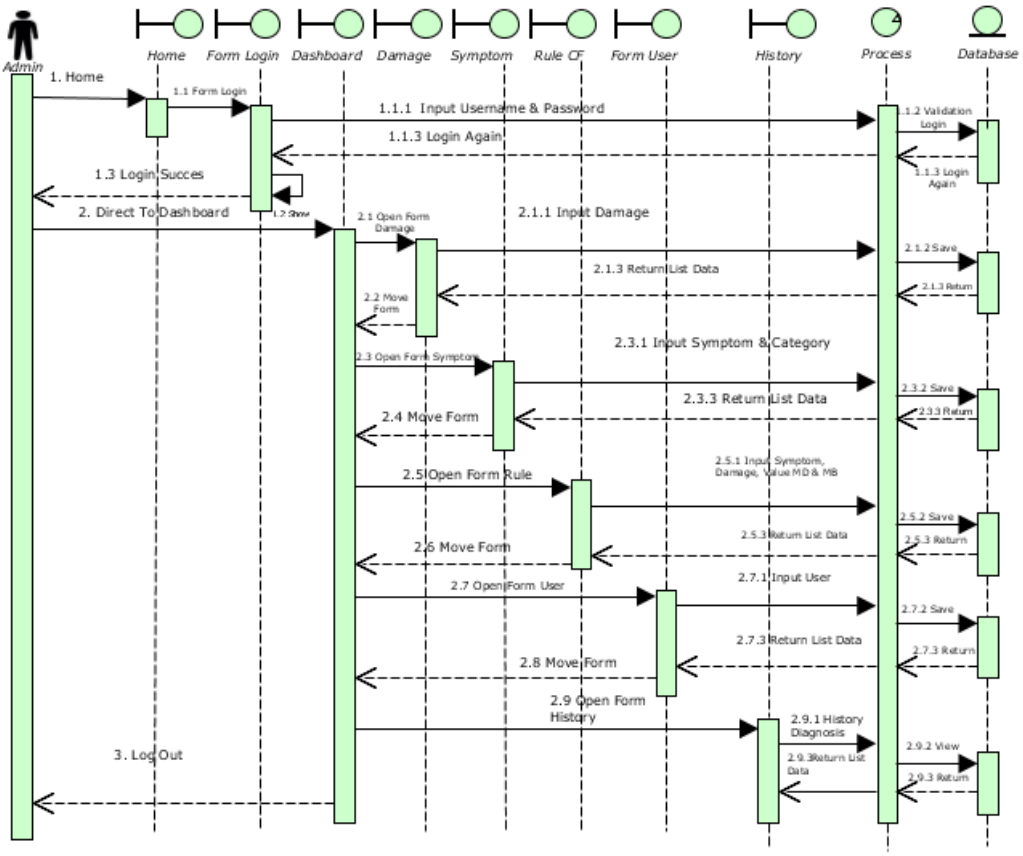

Figure 8. Sequence Diagram Admin

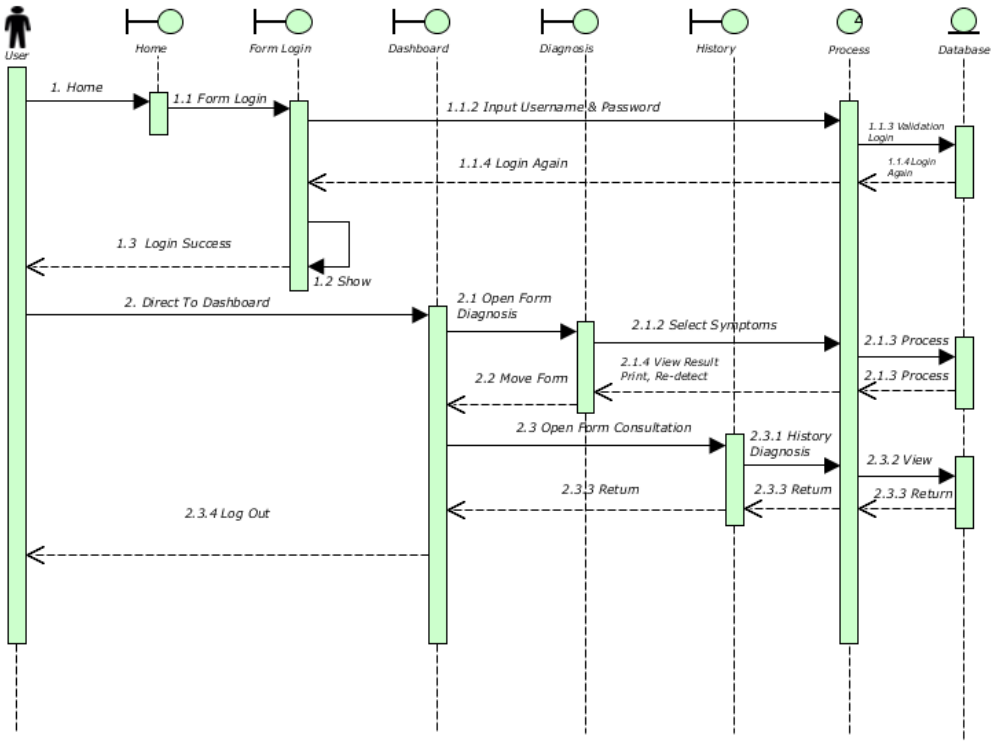

Figure 9. Sequence Diagram User

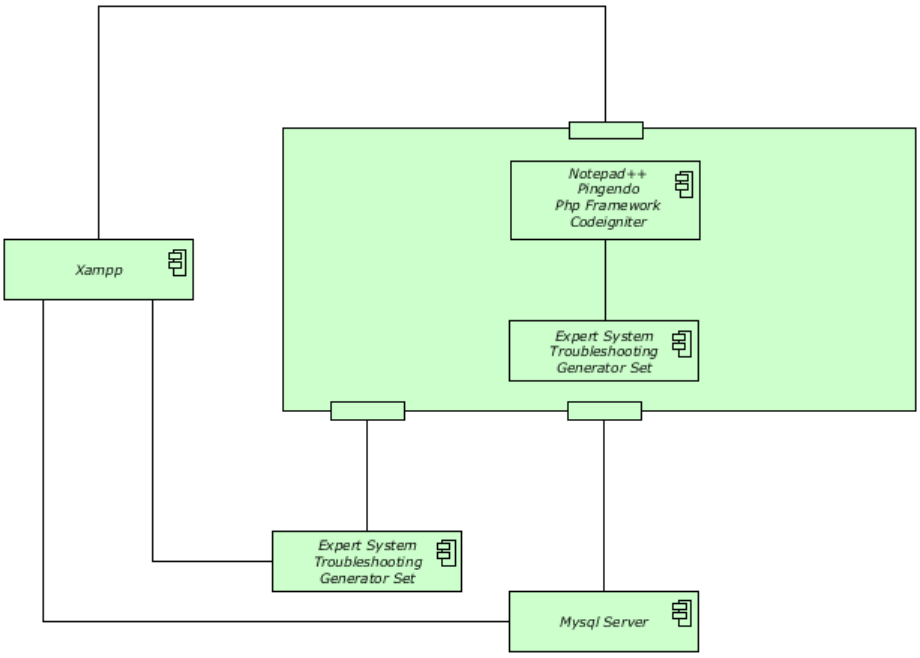

Figure 10. Component Diagram

Knowledge Base

A knowledgebase is to present knowledge from an expert and put into a system so that the relationship among one knowledge and others can be known and used to test the feasibility of reasoning. Table 2 explains the mb and md values for each symptom of generator damage.

Table 2. MB and MD Values in Generator Damage Symptoms

Certainty Factor Value			
Code	Symptoms Name	MB	MD
G001	Engine is unable to *start*	0.79	0.02
G002	The engine wants to start but dies again soon (without smoke)	0.71	0.07
G003	The engine will start but will soon die again (smoke coming out)	0.69	0.05
G004	Engine low power (normal smoke)	0.80	0.06
G005	Engine low power (white smoke)	0.72	0.08
G006	Engine has low power (black smoke)	0.73	0.06
G007	Knocking sound loud (knocking)	0.74	0.07
G008	Engine noise is not normal	0.65	0.05
G009	The sound of burning is not normal	0.68	0.09
G010	Hunting machine (at idle rotation)	0.81	0.1
G011	Hunting machine (at normal rotation)	0.82	0.09
G012	Engine vibration is quite strong	0.83	0.08
G013	The engine is slow to idle speed	0.77	0.07
G014	Wasteful of fuel	0.75	0.05
G015	Wasteful of oil	0.82	0.11
G016	Oil mixed with diesel	0.74	0.14
G017	Oil mixed with water	0.66	0.08
G018	Low oil pressure	0.69	0.09
G019	The gas pipe exits quite a lot of gas	0.85	0.11
G020	Engine temperature is too high (overheat)	0.78	0.08
G021	Engine temperature is too low	0.81	0.07
G022	Inlet air pressure is low / less	0.86	0.05
G023	*Bad oil pressure regulating valve*	0.81	0.07
G024	*High exhaust gas temperature*	0.77	0.06
G025	*Battery drop*	0.71	0.04
G026	Selenoid does not open	0.82	0.07
G027	Selenoid damaged	0.73	0.06
G028	Oil pressure shaking / needle point is stick	0.70	0.02
G029	Temperature meter shaking/ needle point is stuck	0.69	0.11
G030	The charge indicator light is on	0.72	0.08
G031	Starter lasts long / does not want to stop	0.73	0.06
G032	The alarm sounds continuously	0.74	0.07
G033	The engine suddenly died	0.65	0.05
G034	RPM Engine cannot be high	0.68	0.09
G035	Hunting / rocking machine RPM	0.81	0.1
G036	RPM engine is droop	0.82	0.09
G037	The pilot light is not on	0.83	0.08
G038	Ampereter is not pointing	0.77	0.07
G039	The frequency is not visible	0.75	0.05
G040	Voltage does not come out	0.79	0.11
G041	Voltage does not come out	0.80	0.12
G042	Less voltage	0.72	0.13
G043	Voltage is too high	0.75	0.08
G044	Unstable voltage	0.78	0.07
G045	Voltage is unbalanced between phases	0.69	0.12
G046	Starter voltage is not balanced	0.72	0.09

G047	Unstable voltage	0.72	0.11
G048	Shock load response is not fast enough	0.83	0.06
G049	Voltage drops	0.84	0.05
G050	Voltage is too high	0.80	0.09

Manual Calculation Certainty Factor

The symptom data chosen by the user has MB and MD values that are used to determine the CF value with a combination of 3 (three) selected symptoms. Based on the symptoms above, MB, MD and CF result obtained from PT. ZT (Mechanical) as shown in Table 3 is damage data that is connected with 3 (three) symptom data.

Table 3. Damage Data Linked to Symptom Data

Symptoms Selected	Damage Indicated
The engine doesn't want to start	The solar filter is clogged
The engine will start but will soon die again (without smoke)	The diesel filter is clogged
The engine is lacking power (normal smoke colour)	A solar filter is clogged

In Table 3, it can be seen the damage connected with the symptoms of user choice. These defects have a percentage of each in the system. It will only display the top 2 damage from damage which has the highest percentage. A manual calculation of each damage is described as follows.

1. Manual calculation of clogged solar filters.
   CF Value = 0.79 – 0.02 = 0.77 (Symptom 1)
   Result = 0.77 * 100% = 77%
2. Manual calculation of clogged solar filters.
   CF Value = 0.71 – 0.07 = 0.64 (Symptom 2)
   Result = 0.64 * 100% = 64%
3. Manual calculation of clogged solar filters.
   CF Value = 0.69 – 0.05 = 0.64 (Symptom 3)
   Result = 0.64 * 100% = 64%
4. Manual calculation of clogged solar filters
   MB = 0.79 + 0.71 * (1 – 0.79) (MB Symptom 1 & 2)
   = 0.79 + (0.71* 0.21)
   = 0.79 + 0.1491
   = 0.9391
   MD = 0.02 + 0.07 * (1 – 0.02) (MD Symptom 1 & 2)
   = 0.02 + (0.07 * 0.98)
   = 0.02 + 0.0686
   = 0.0886
   CF = 0.9391 – 0.0886
   = 0.8505 * 100%
   = 85.05
5. Manual calculation of clogged solar filters
   MB = 0.9391 + 0.69 * (1 – 0.9391) (MB End & Symptom 3)
   = 0.9391 + (0.69 * 0.0609)
   = 0.9391 + 0.042021
   = 0.981121
   MD = 0.0886 + 0.05 * (1 – 0.0886) (MD End & Symptom 3)
   = 0.0886 + (0.05 * 0.9114)
   = 0.0886 + 0.04557
   = 0.13417
   CF = 0,981121 – 0.13417

= 0.846951 * 100%

= 84.6951% or 84.7%

The results of manual calculations show all damage types connected with the symptoms chosen by the user, with the percentage of each. The system displays the results of analysis, diagnosis results, conclusions and suggestions with the highest percentage first. The results of user consultation can be seen in Table 4.

Table 4. User Consultation Results

Result of analysis		Diagnosis Results		
No	Symptoms	No	Damaged	Level of confidence
1	G001 The engine won't start	1	K009 Clogged Solar Filter	84.7%
2	G002 The engine will start but will soon die again (without smoke)			
3	G003 Engine low power (normal smoke colour)			
Conclusion: Based on the symptoms chosen, Genset is predicted to experience Damage ➽ Clogged Solar Filter with confidence level ➽ 84.7% **Solution:** ➽ Clean Change the Solar Filter				

Application

This section will explain the module design of the home form program, admin form, consultation form, diagnostic results form and user history form.

Figure 11. Homepage Form

Figure 11 shows the homepage form. This form is the main form display on the system, on that form, some navigation can be accessed including:

a) Home Navigation
   This navigation is used to return to the homepage form.
b) Profile Navigation
   This navigation is used to view the company profile.
c) Vision Navigation

This navigation is used to see the company's vision.

d) Mission Navigation
This navigation is used to see the company's mission.

e) Login Navigation
This navigation is used for user logins to enter the system.

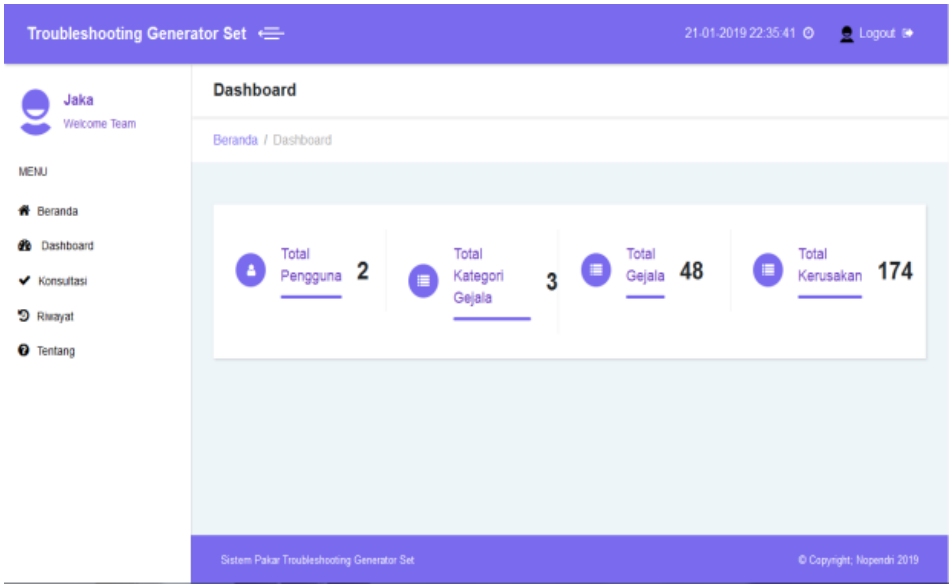

Figure 12. Dashboard User

The form in Figure 12 is a display of the user dashboard on the system, there are total system users, categories of symptoms, symptoms, damage, and navigation on the left that can be accessed including:

a) Home Navigation
This navigation is used to return to the homepage form.

b) Dashboard Navigation
This navigation is used to view or return to the user's dashboard.

c) Consultation Navigation
This navigation is used to diagnose the damage.

d) Navigation History
This navigation is used to view the user's diagnostic history.

e) Navigation About
This navigation is used to see the team profile.

The form in Figure 13 is an admin dashboard display on the system, there are total system users, symptoms categories, symptoms, damage, and navigation on the left that can be accessed including:

a) Home Navigation
This navigation is used to return to the homepage form.

b) Dashboard Navigation
This navigation is used to view or return to the admin dashboard.

c) Damage Navigation
This navigation is used to add, edit, and delete damage.

d) d) Navigation of Symptoms
This navigation is used to add, edit, and delete symptoms.

e) User Navigation
This navigation is used to add, edit, and delete users.

f) Navigation History
This navigation is used to view the user's diagnostic history.

g) Navigation About

h) This navigation is used to see the team profile.

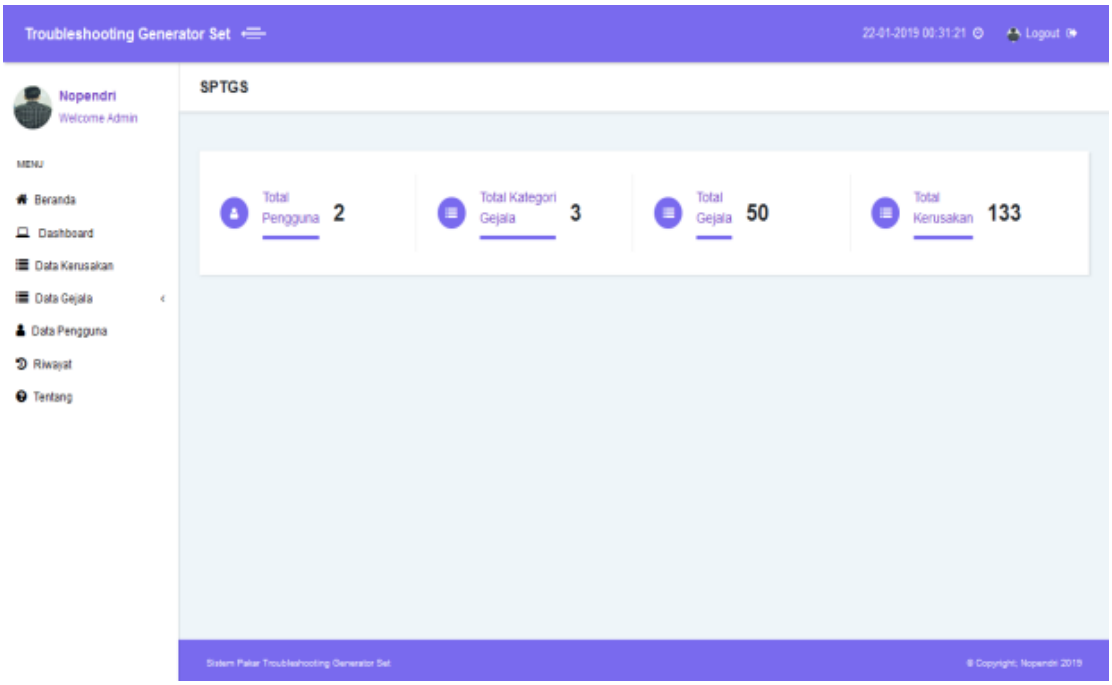

Figure 13. Admin Dashboard

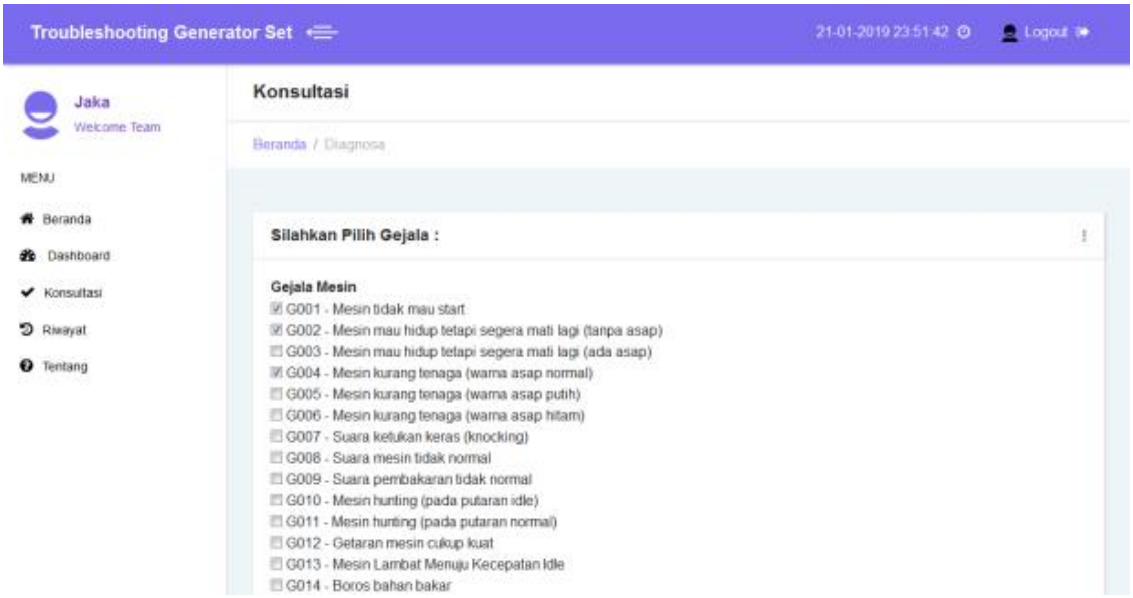

Figure 14. Consultation Form

The form in Figure 14 is the appearance of a user consultation on the system, there are all symptoms based on categories, then the user checks the symptoms that correspond to the damage experienced.

The form in Figure 15 is a display form the results of user consultations on the system, there are analysis results, diagnosis results, suggestions, solutions, as well as the percentage value of the certainty of damage to the generator.

The form in Figure 16 is a display from the results of user consultation history on the system, on the form, there are selected symptoms, days, dates, values, and solutions to prevent damage to the generator.

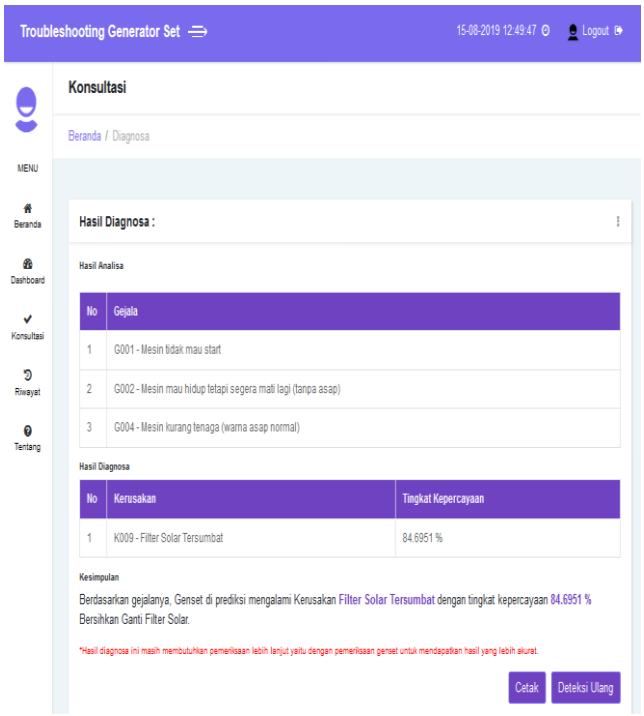

Figure 15. Diagnosis Form

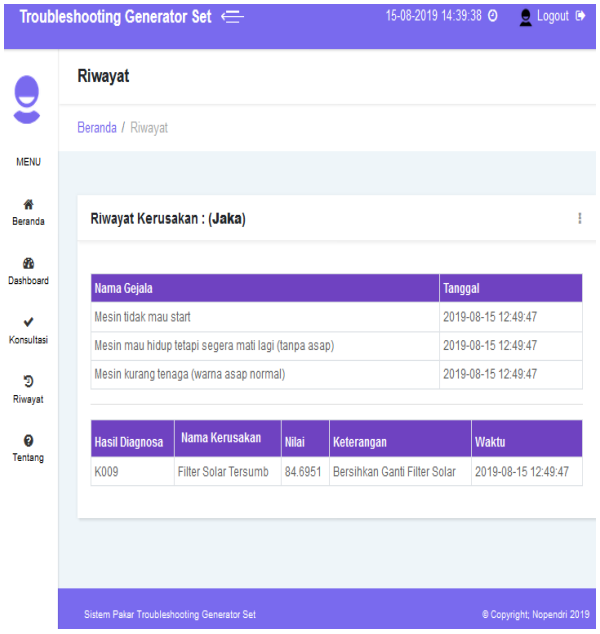

Figure 16. User History Form

4.0 CONCLUSION

Based on research and discussion that has been done before, the following conclusions are obtained:

1. With the expert system able to complete the existing troubleshooting on the PT. Telkomsel by PT. ZT uses a certainty factor expert system with depth-first search in web-based generator set troubleshooting.
2. With the application of the certainty factor method with depth-first search in the generator set troubleshooting system, it can help the corrective team of PT. ZT provides an initial prevention solution to damage to the generator set. So that PT. ZT does not require the services or expertise of a mechanic in solving repair problems if it is damaged improperly and becomes effective, efficient and can determine the value of certainty of the damage solution.

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