

DESIGN OF ATS (AUTOMATIC TRANSFER SWITCH) SYSTEM BY INTEGRATING PLC (PROGRAMMABLE LOGIC CONTROLLER) AND INVERTER

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ABSTRACT

Continuous and reliable electricity cannot be ensured to be available at all times. Therefore, to meet the needs of electrical energy continuity, backup or alternative sources of electrical energy are also utilized such as generators. Genset as a backup energy source will replace the function of PLN electricity which is the main energy source. Switching from PLN electricity to generators or vice versa requires equipment to regulate it known as ATS, but conventional ATS responds when there is a change in the electrical system usually has a generator starting time lag (up to 30 seconds). This is certainly detrimental to users who need a continuous source of electricity, such as shop cash registers. In this research, an ATS panel is built with the integration of PLC and inverter control. PLC will replace the limitations of relays and timers as controllers with simple wiring and programmable logic circuits as needed. The ATS system built is able to switch the inverter load in approximately less than 0.05 seconds when the PLN power source goes off and is able to run the generator on the first start to supply power to the main load as well as switching the inverter load to the main load supplied directly from the generator. So that lighting or other loads can be maintained in the order of a long time for the generator starting process or until the generator repair conditions if it fails to start.

Keywords: genset; ATS; PLC; inverter; load switching

INTRODUCTION

The human need for electricity is inseparable, it is because electricity has become one of the mandatory human needs because it has an important role in every human activity. If you look at the development of technology every year that always changes with its sophistication, this certainly goes hand in hand with changes in the increasing need for electrical energy.

State Electricity Company (PLN) has the authority to regulate the distribution of electricity in Indonesia must work extra if there is an increase in electricity demand in the industrial, residential, commercial and other user sectors. Electricity users at all times demand that the supply of electricity supply is always continuous and stable but it cannot always be guaranteed by PLN as a provider of electrical power. Blackouts are still found in some areas either due to interference or there are maintenance activities that turn out to be fatal to users. It is said to be fatal because a few minutes of supply outage can cause material losses and even loss of life, for example for users such as industry, banking and hospitals.

Therefore, for users whose category is users with critical loads (loads that are always supplied 24 hours), there is a backup of PLN electric power in the form of generators as a backup power supply. The use of generators is currently found everywhere but in general the operation is still manual and there is still a time gap in switching the power source to the backup power source in this case the generator. The operation of the generator still uses human power (operator) which certainly has some disadvantages in terms of speed and security. In addition, the ATS system that is built always has a time lag from starting the generator to the transfer of PLN's electricity source to the generator approximately 10 to 20 seconds and even more than 30 seconds because it depends on the condition of each generator backup source. This condition is very detrimental to those who

need a continuous source of electricity, for example a business field that requires continuous lighting at its operational time such as a conventional shop (Rahmad Meubel shop) which is also one of the partners requiring lighting during operation or medical equipment connected to the patient and working continuously, etc.. So it is expected that in the process of switching electricity sources to backup sources, other backup sources must still be supplied for lighting needs and or to maintain the need for continuity of electricity sources in the use of certain electrical equipment until there is a full transfer of electricity sources to the backup power source generator.

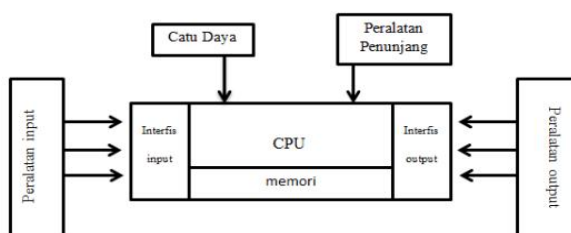
In order to fulfil the above conditions, a device will be built that is able to run the generator automatically without an operator but this system still supplies electrical power while switching electricity sources from the PLN electricity source to the generator. Researchers will build an ATS (Automatic Transfer Switch) device using a PLC (Programmable Logic Controller) as a controller that simultaneously regulates the supply of emergency power sources using inverters for lighting needs and other power source needs during this ATS system to switch PLN power sources to backup genset power sources to overcome the supply of electrical power during the transfer period until the entire electrical load is fully transferred to the backup genset power source.

THEORETICAL FRAMEWORK

ATS (Automatic Transfer Switch) is an automatic switch if the power supply from PLN is cut off or there is a blackout then the switch will switch to other alternative energy sources such as generators. ATS consists of an inverter control circuit that works by connecting the generator to the load automatically when the main power source (PLN) is cut off (Eko Suranto, 2013).ATS can work with several modes of operation, namely manual mode and automatic mode. Manual mode on the ATS does not respond automatically in carrying out commands but is done manually. As for the automatic mode, an automatic response to system changes can be obtained (Paul Hendry Ginting et al., 2014).

In automatic mode, ATS is able to respond to failures in the main power source (PLN) and mengalitfkan alternative sources. The ATS will detect the presence or absence of voltage using a low voltage relay or voltage sensor. In order for the residual voltage at the main source terminal to completely disappear, a delay of 2-5 seconds is required before the ATS separates the load from the main power source. The ATS then gives a signal to recognise the generator set as an alternative source. The ATS can connect to the generator set in less than 10 seconds. When switching to the main power source will activate the timer on the ATS to ensure the main source has returned to normal. The delay time for open and closed transitions to occur ranges from 5 to 15 seconds.

PLC (Programmable Logic Controller) is a control device that replaces mechanical relays in control systems. PLC as a control device with a simpler circuit because it can be programmed using diagram-based software (Wahyu Widiyanto et al, 2012). The way the PLC works is to receive an input signal from the controlled process and then execute a number of logic commands on the input signal in accordance with the programme stored in memory. Furthermore, an output signal is obtained to control the equipment. The following is a block diagram of a PLC control system.



Sourcer: Indah Chaerunnisa et.al, 2018

Picture 1. PLC Omron CPM2A

The Omron CPM2A PLC consists of 20 ports which are divided into 8 output ports and 12 input ports. There are also 4 indicator lights namely PWR (green), RUN (green), COMM (yellow) and ERR/ALM (red) (Sugijono, 2017).



Source: Sugijono, 2017

Picture 2. PLC Omron CPM2A

Generator sets or commonly known as generators are an alternative energy source if the main energy source from PLN is disconnected. The generator functions to convert mechanical energy from the driving engine into electrical energy. The rotating part of the generator is the rotor while the stationary part is the stator. The working principle of an alternating current generator is that the rotating rotor cuts the magnetic lines on the stator and forms an induced emf which is then channelled to the output coil.

There are two types of generators, namely open type generators and silent type generators. Open type generators are equipped with a control panel so that they are easy to read, oil tanks and drain pipes that are attached directly to the engine. They tend to be larger and noisier and produce exhaust gases that should be discharged outside the room. The silent type generator set is a generator set that has a housing coated with sound absorbers but its structure is similar to the open type generator set (Didik Aribowo, 2020).

Gensets receive mechanical energy from diesel engines that convert heat energy from combustion into motion. The fuel used is oil (diesel) which can burn when given high pressure air. Because it works using compressed air pressure in a high pressure cylinder so that the temperature in the cylinder rises. When the fuel is sprayed into a high-pressure cylinder with a temperature greater than the flash point of diesel fuel, the diesel will burn in the cylinder (Alfith, 2017).

Inverters are used to convert direct current into alternating current with adjustable frequency. The inverter gets a direct current source from the accumulator /aki which is then through the process of switching on the semiconductor components in the inverter circuit. The difference between single-phase, two-phase, and three-phase inverters is in the number of conductors. In a single-phase inverter there are two conductors, namely the phase wire and neutral wire. In two-phase and three-phase inverters there are three or four conductor cables plus one neutral cable (Ray Mundus et al, 2019).

METHOD

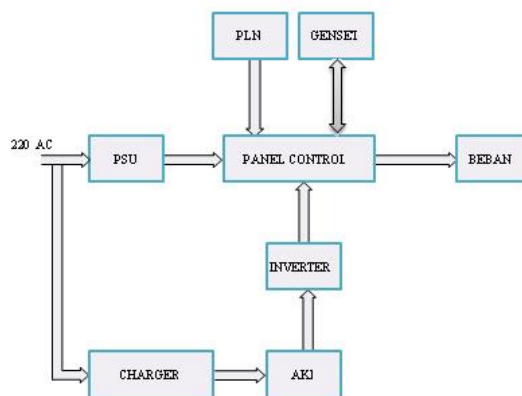
When viewed from several categories of research, namely based on its use, this research is applied research because there is a solution to practical problems. Meanwhile, based on the method this research is evaluation research because data processing will be carried out from several experiments to support decision making. Based on the type of data and analysis, this research is a combination of qualitative and quantitative research. Quantitative research because there is a

process of measuring the work of ATS and inverters such as current, voltage, etc. The test results will be analysed and produce a result. The test results will be analysed and produce a study through observations based on tool trials is a type of qualitative research.

Based on the data source, there are two types of data used, namely primary data and secondary data. Primary data is obtained directly at the partner location through observation (observation) or interviews. Researchers observed conventional generator systems in the field and obtained information about the function and work of generators and their limitations directly from users. While secondary data is obtained through information obtained in books or journals that help researchers in problem solving because it is supported by supporting theories.

Based on the type of data described, there are two methods of collecting research data, namely observation, interviews and literature studies. Problems are obtained through observations, interviews and problem solving can be supported through literature studies. The methods used are descriptive and evaluative. The descriptive method was used in the initial research when collecting data based on current conditions. Data analysis is carried out descriptively, namely describing or describing the data collected during research to tool testing (Sugiyono, 2014). While the evaluative method is used in evaluating trials of making or developing a product as a solution to problems. This method systematically measures the results of research related to the effectiveness of the tool whether it is in accordance with the planned objectives or not (Arikunto, 2003).

The operational definition aims to create a common perception related to the research to be carried out. Operational definitions are used to equalise the possibility of diverse understanding between researchers. This research is a product development of ATS (Automatic transfer switch) from manual control to automatic control using PLC. There are two circuits that will be built on the ATS panel, namely the power circuit and the control circuit. A control system will be built whose settings are adjusted to the needs through programming using ladder diagrams. In its development there are additional devices needed besides ATS, PLC, and generators. There are batteries, inverters, relays, MCBs, and other components such as cables needed in the construction of PLC-based ATS.



Source: author, 2023

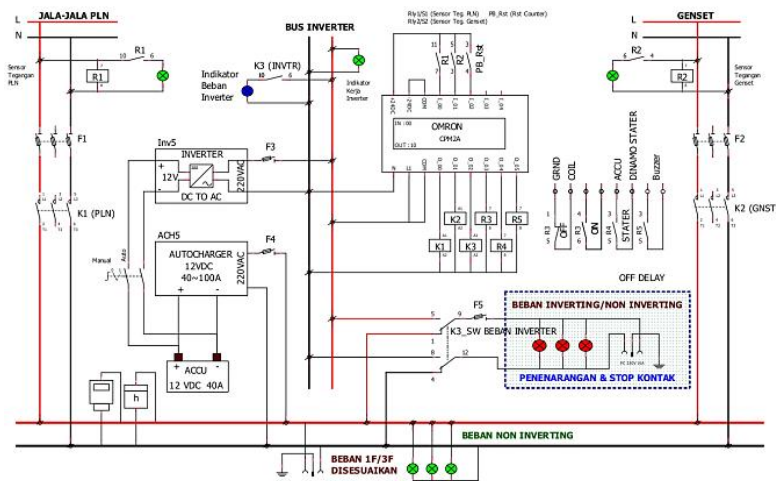
Picture 3 :Block diagram of ATS panel working system

DISCUSISON

Results of ATS (Automatic Transfer Switch) System Design by integrating PLC and Inverter.

ATS (Automatic Transfer Switch) by integrating PLC and Inverter will control the transfer switch system for the process of switching the main power source of the PLN network to the backup power source of the generator. Figure 6 shows how the wiring diagram of the ATS system design results by integrating the PLC and inverter. Based on the wiring diagram, it can be seen that

the PLC as a programmed control device to maintain special power from the battery source through a DC to AC inverter for some lighting loads and power at certain sockets during the process of transferring or switching the PLN grid power source to a backup source, in this case using a generator.



Source: author, 2023

Picture 4. Wiring diagram of ATS control with PLC and Inverter

The ATS system has three power contactors to distribute the load, namely K1, K2 and K3. Each K1 distributes the load from the PLN network source to the load if the main source of the PLN network is active, K2 distributes the power source from the backup power source of the generator, and K3 distributes a special power source served by the inverter during the transition time of switching the main source to the backup source (including the starting process of the generator) and vice versa when switching the backup power source to the main power source when the PLN network is active again. The work of the inverter here is intended to keep a long blackout to avoid the occurrence of things that are not desirable due to power outages for consumers. The work of each power contactor K1, K2 and K3 is controlled by a PLC (Programmable Logic Controller) which has been programmed in advance so that the PLC works according to the desired ATS control description.

In addition to controlling the power contactor, the PLC also controls several relays (R3, R4 and R5) to On/Off the generator set and start the generator set automatically when there is a light outage on the main source of PLN mesh. The PLC will automatically detect the main source of PLN mesh whether the status is on or off through relay R1, then make a decision to switch the load to the inverter load source and start the generator and switch the main load to the backup power source generator. In some time the PLC switches the inverter load to the backup power source of the generator. So that the inverter load is now supplied by the generator set power source. The load switching time occurs only as fast as the K3 contactor relay works as a power switch, which is less than 1 second.

The presence of generator voltage is detected by R2 to the PLC so that the PLC can switch the load to the generator backup power source. As long as the main source of PLN mesh is not active (On), the load is still served by the generator. However, when the PLN grid is back on, the PLC detects the PLN voltage through R1 and some time later activates the K1 power contactor to supply the power source from the PLN grid to the load and at the same time the K2 genset contactor opens and disconnects the source from the genset to the load.

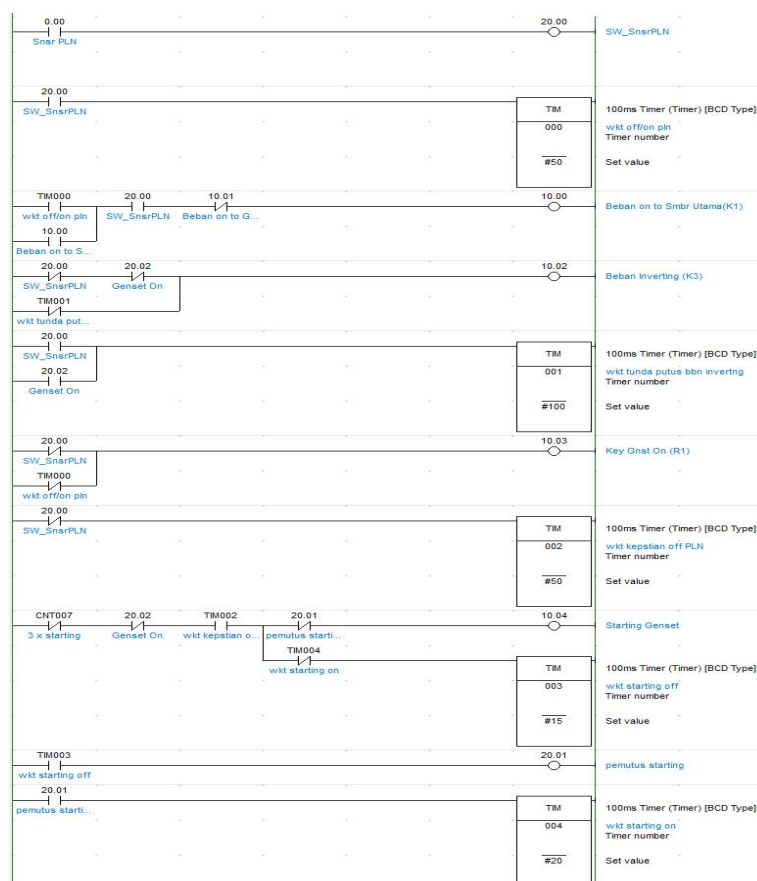


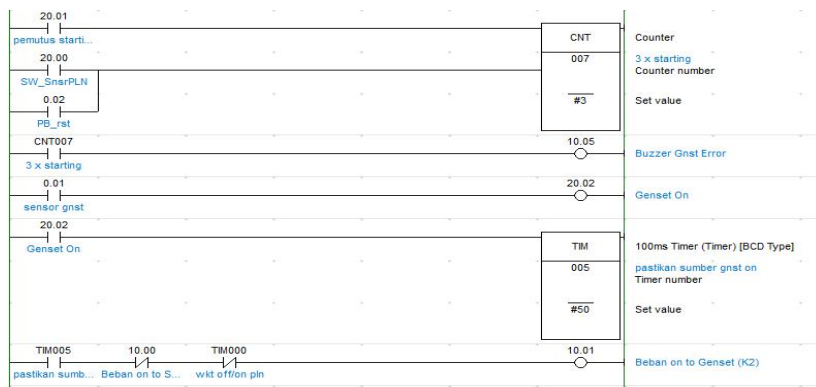
Source: author, 2023

Picture 5. Design results of the simulation panel and generator as a backup power source

Results of PLC Ladder Diagram Design and Testing

The results of the PLC ladder diagram design are shown in Figure 8 where the PLC ladder diagram uses five timers and one counter. This ladder diagram is designed according to the ATS control description by integrating PLC and inverter as an emergency backup source in the transition of the main power source outage from the PLN grid.





Source: author, 2023

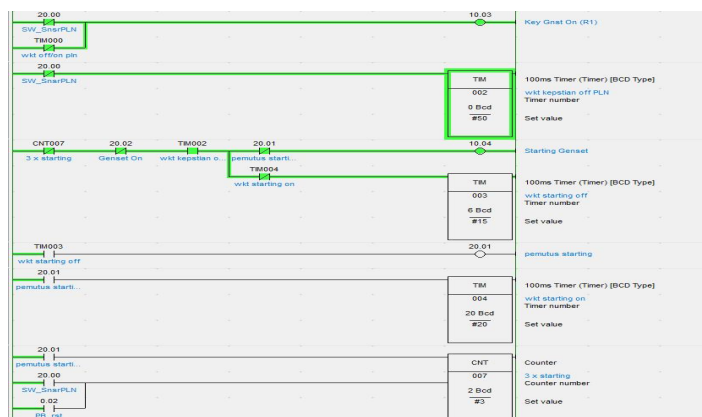
Picture 6. PLC ladder diagram design for ATS control by integrating PLC and inverter.

The PLC ladder diagram is designed to detect the voltage of the PLN main source and the voltage of the generator backup source. When the PLN grid source is on, the load has not been completely connected to the main source, the PLC will take time to confirm whether the PLN grid main source is really on within 5 seconds, then the load is switched to the main source. During this time, the PLC switches the special load to the inverter (becomes the inverter load) for 10 seconds, so that when the main load is supplied by the main source of the PLN grid, 5 seconds later the PLC switches the inverter load to the main supply so that all loads are carried by the main source of the PLN grid. When the main power source of the PLN grid goes off, the generator is in the on/standby position, but has not started the generator, meaning that the generator is in a waiting position to ensure that the main power source of the PLN grid is completely off. This condition can be seen in Figure 12 in the output bit 010.03 in the on/standby position, if within 5 seconds (TIM002) the PLN grid power source is still off, then starting the generator set occurs through the output bit 010.04 in Figure 13, with the length of time bit 010.04 on start is 3 seconds then off.

Results of Genset Starting Experiment

Experiment starting generator in the control programme is made repetition of three times (3x starting), assuming if the first stater fails can be done second stater to third stater. If the third starting genset fails then the system sounds an alarm / buzzer that mendakan genset stater process fails, so it is necessary to make improvements to the generator.

Figure 6 shows the experimental results of the ladder diagram function to start the generator when the main power source is off. The PLC has been programmed to start the generator three times if the first and second starts fail (the generator cannot operate, possibly due to oil, lack of battery power, and so on which can cause the need to do maintenance on the generator).



Source: author, 2023

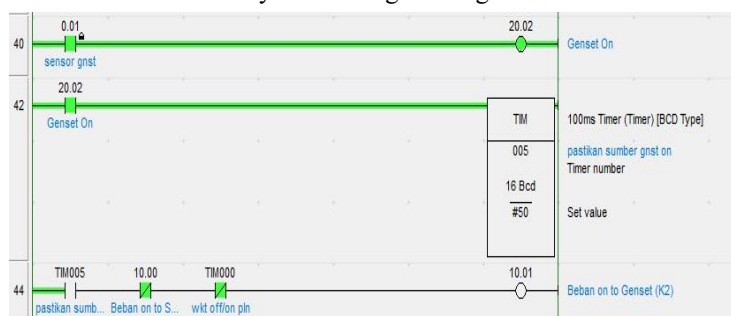
Picture 7. Cutaway ladder diagram of generator set starting

If three times the starting genset fails, the PLC will sound an alarm signalling the genset needs to be repaired (maintenance & Repair). Counter (CNT007) on the PLC according to the test results have been functioning properly that is able to count the number of starting generators for three times and stop the starting process and turn on the buzzer / alarm as shown in Figure 10 When the generator set is in a state of repair, special loads are still served by the inverter until the time limit is determined according to the available battery capacity.



Source: author, 2023

Picture 8. Cutaway ladder diagram of generator set fail on



Picture 9. Cutaway ladder diagram when the genset is on and supplying power to the main load

When in the condition of waiting for the genset backup power supply through contactor K2 by PLC, the special load (inverter load) continues to be served by the inverter, up to 10 seconds after contactor K2 is activated by PLC to supply electrical power to the main load. In the 10-second time condition, the inverter load is switched to the main load with a backup power source from the generator set. The following test results are tested when the main electricity source PLN mesh on, the ATS system with PLC control does not immediately divert the main load to the PLN mesh source but waits for some time (5 seconds) to ensure correctly that the main electricity source PLN mesh has been completely on, then the process of diverting the main load to the PLN mesh power source through contactor K1 occurs.

Inverter Work Result

The inverter used in this experiment is an inverter with a power capacity of 1200VA with the battery capacity used is 12Vdc 40Ah voltage. To serve loads that are continuous and temporary loads (inverter loads) from some of the main loads in anticipation of emergency lighting and other sources of electricity that are considered necessary continuously. Continuous loads are PLC control circuits and relays and contactors, while temporary loads such as certain (special) loads are supplied by the power source from the inverter in the event of a blackout and load switching from the main source to the backup generator source.

The ATS control system is controlled by a source that comes from the inverter. This is intended so that when the power source from the PLN network and the backup power source

generator goes off, the ATS control is still supplied with power by the inverter and can regulate the system automatically according to the ATS control concept by minimising the inverter load switching time so that the power source is maintained for certain loads during a power outage.

Table 1 shows the work of the inverter on the inverter load (emergency load), where the inverter function in addition to supplying electricity sources to control loads such as PLCs, contactors and some relays and inverter indicators, also serves inverter loads which are some lighting loads and special sockets in the event of a power outage on the PLN network until the backup source of the generator is activated.

Experiment	Load			Remark
	Mainly (PLN)	Inverter	Genset	
First system On	Off	On	Off	PLN On, the special load is supplied by the inverter until the main load is supplied by the PLN grid.
	On	On	Off	
	On	Off	Off	
PLN Off	Off	On	Off	Special loads are supplied from the inverter
Genset On	Off	On	On	Special loads remain supplied from the inverter even if the genset is on until the specified time the inverter loads off and switches the load to the genset power source.
	Off	Off	On	
PLN On	Off	On	On	PLN On, Inverter keeps the special load until the main load is supplied by PLN grid power source
	On	Off	Off	

Source: author, 2023
Load Switching Time

The load is the electrical load served by the main power source of the grid and the backup power source of the generator. The intended electrical load is divided into two parts, namely the main load and the special main load (inverter load). The main load in question is a load that is fully served only by the main power source of the PLN grid or from the backup power source of the generator. While the special main load (inverter load) in addition to being served by both the main source of the PLN grid and the backup power source, this special load is also served by the inverter when there is a power outage of the main PLN grid and during the switching process. The goal is to maintain a special source of electricity and lighting in the event of an outage for some time according to the desired design.

Based on the test results of the ATS system by integrating the PLC and Inverter, the results show that the switching of special main loads by the PLC occurs when the main source of the PLN grid goes off for less than 1 second. The K2 contactor switches on via PLC output bit 010.01 to supply generator power to the main load. The 5 second time is intended to ensure that the generator set has actually worked properly and has supplied backup power under normal conditions.

Calculation of Battery and Inverter Capacity Based on Loading

The calculation results for a modelling of battery power usage with an inverter for a certain length of time. Table 2 below is the result of calculating the capacity of batteries and inverters as an alternative source of electricity capable of supplying loads with a minimum backup time of 1 hour. The load power is calculated based on the PLN power installed to the customer's meter. The inverter capacity is determined from the Pload.

Table of calculation results of battery and inverter capacity for a duration of 1 hour

No	Power	Baterai capacity 12V	Inverter Capacity
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	instaled (VA)	Current (Ah)	Power (Wh)	instaled (W)
1	1300	92	1105	1200
2	2200	156	1870	2000
3	3500	248	2975	3000
4	4400	312	3740	4000
5	5500	390	4675	5000

Source: author, 2023

CONCLUSION

Based on the results of the ATS system design by integrating PLC and inverter, it produces the following conclusions:

1. The Automatic Transfer Switch (ATS) system has been built using PLC as a control centre and inverter as a backup power source supply when the PLN grid power source goes out and can maintain the power source as long as the battery is capable of being used while waiting for the generator starting process to supply a backup power source.
2. The ATS system is able to switch the inverter load in approximately less than 0.05 seconds when the PLN grid power source goes off and is able to run the generator on the first start to supply power to the main load as well as switching the inverter load to the main load supplied directly from the generator.
3. The inverter works continuously to supply power to the control system, namely the PLC, contactor and control relay, besides that the inverter functions to serve the inverter load which is part of the main load that is diverted to the inverter source in less than 1 second when the PLN grid source goes off, so that lighting or other power sources can be maintained in the order of a long time for the generator starting process or until the generator repair conditions if it fails to start. The length of time is highly dependent on the load capacity and battery capacity.

Based on the research results and conclusions above can be suggested as follows:

- a. Determining the inverter load should look at the capacity of the inverter and the installed battery, as well as the focus of the load, namely whether it is more to lighting or other loads such as for sound system loads if this system is applied in houses of worship, and or offices that require a source of electricity for work devices such as computers and so on.
- b. Determining the length of time to use the inverter load during a blackout on the main electricity source PLN mesh, should be calculated installed power and the desired length of time to determine the capacity of the inverter and battery capacity.
- c. The capacity of the inverter and battery used should be adjusted to the load used with the calculation of the length of use.

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