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OPTIMISATION OF THE AUTOMATION PANEL OF AN ELECTRIC GENERATING SET

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Abstract: Generators are used to ensure continuity of electricity supply to consumers. These electric generating sets must meet all the standards requirements referring to the quality of the electricity supplied. The paper presents an analysis of a diesel generator set and identifies possibilities for optimising its automation panel. The optimisation consisted of the use of a thicker metal plate sheet to better resist vibrations, the introduction of a heating system capable of eliminating condensation from the panel, and the use of a programmable logic controller capable of ensuring proper operation of the generator set, as well as its remote control and monitoring. Testing of the generating set on which the automation panel was optimised showed that it is working properly and successfully fulfils its required functions.
Keywords: generator set, power quality, results investigation, monitoring

1. INTRODUCTION

For the distribution and supply of electricity to consumers there are certain requirements regarding voltage, frequency, harmonics, continuity of supply, etc. that must be fulfilled [8, 15–17]. All these requirements must be met by generating sets, too, especially bearing in mind that improper operation can lead to breakdowns, explosions, even loss of lives. For these situations, generating sets are classified into safety categories, depending on their importance and need in the electricity supply process [7].

In situations where generators are used to supply electricity to isolated communities, they can operate as part of a complex micro–grid system, which combines the generator sets with photovoltaic and/or wind systems and battery banks to store the energy produced [1, 3, 20]. In configurations that include wind generators, the generator set are also used to control the frequency in the event of a sudden increase in load [18]. When the generator set is configured in a combination with photovoltaic panels, the generator is also used to ensure that maximum power is extracted from the panels, to compensate for harmonics caused by non–linear loads, and to compensate for reactive power supplied by inverters and/or demanded by consumers [22].

In most cases, a programmable logic controller is used to control and monitor the electric generator, allowing it to be integrated into a SCADA system. This can automate various functions: start/stop, local or remote diagnostics, setting of operating parameters, etc. [2, 21]. The frequency and the supplied voltage are regulated by electronic PID controllers [5,6].

Of particular importance in the operation of generating sets is their parametrisation. Parametrization is carried out by means of dedicated software, establishing a complete set of parameters for which the optimal value must be chosen out of their variation range, depending on the chosen algorithm [9]. A heuristic algorithm can be used for parameterization and identification of initial estimates in the first step, followed by a modified Levenberg–Marquardt algorithm designed to fine–tune the solution based on the first step performed [12].

The disadvantages of using generators to supply consumers with electricity are fuel costs and pollution through gas emissions into the atmosphere.

For optimum fuel consumption, the generator set should be operated at 80 to 85% of its capacity [19]. The fuel consumption can be influenced using a regulating device, consisting of a controller and an associative memory block, capable of determining the optimal speed of the internal combustion engine shaft and controlling its fuel supply. Thus, for small loads, the device allows fuel consumption to be reduced by almost 30% [4].

Although the disposal of exhaust gases into the atmosphere is a disadvantage, the efficiency and power of the generator set can be increased by recovering the waste heat from exhaust gases and using them in thermal power plants [14].

Increasing the operational reliability of generating sets is achieved through proper maintenance and regular inspection so that they are able to operate and supply electricity at all times in accordance with the required quality requirements [13, 23]. Operating conditions, high temperatures and moral wear and tear can sometimes cause generator set failures. Therefore, it is necessary that after a certain period of operation, a new parameterization of the electric set, an analysis of the operating condition over time, and a replacement of degraded components should be carried out as part of regular maintenance reviews [10, 11].

The paper analyses a classical electric generator set and identifies the possibilities for optimising its automation panel. The optimisation was carried out both from a constructive and a functional point of view. Thus it was proposed to use a larger cross–section metal plate sheet for the automation panel housing, to introduce a heating system to eliminate condensation in the panel, and to add a programmable logic controller to allow, in addition to the classic functions, remote control and monitoring, i.e. integration into a SCADA system. After these improvements were made, the generator set was tested and found to be operating at the appropriate parameters, allowing for local and remote command and control.

2. THE CLASSIC ELECTRIC GENERATOR SET

The main components of a generator set are (Figure 1):

≡ the internal combustion engine, which produces mechanical energy by burning fuel;
≡ the (usually synchronous) electric generator, which converts the mechanical energy received at the shaft from the internal combustion engine into electrical energy;
≡ the control panel, which controls, monitors and protects the entire generating set;
≡ the fuel tank, which is sized as to ensure electricity supply continuity;
≡ the radiator for cooling the heat engine and maintaining a constant temperature during operation;

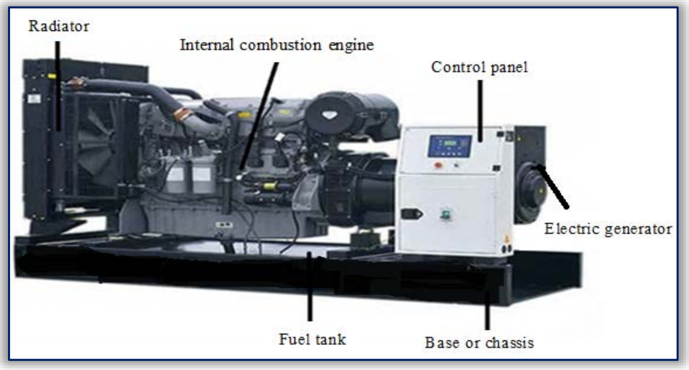

Figure 1. Electric generator set

≡ the base or chassis, to which the engine, generator, tank, radiator, and panel are attached. The base may be fixed or mounted on wheels;
≡ the canopy or casing, present only in enclosed generating sets, which must provide sound insulation and protection against the ingress of dust and water by means of sound–absorbing materials.

The automation panel of the generating set must ensure:

≡ the verification of the voltage supplied by the network to which the consumer, whose redundancy is provided by the generating set, is connected;
≡ the proper functioning of the internal combustion engine by continuously checking the oil pressure, temperature, fuel level and flow;
≡ the proper functioning of the electrical generator, by continuously checking the voltage, frequency and supplied power;
≡ protection of the consumer's power supply by magneto–thermal and differential switch;
≡ protection of the accumulator battery by continuous monitoring of the voltage value at its terminals;
≡ protection of the whole system by using an emergency stop switch.

The main element on the automation panel is the InteliLite NT AMF 9 (Intelligent Lite National Trust Automatic Mains Failure) control module. The interconnection diagram between the module, the consumers, the generator set and the power supply network is shown in Figure 2. This figure identifies how the consumer is connected to the grid, with the AMF 9 module receiving information on the presence or absence of grid voltage.

When the main power grid voltage disappears, the same module, after checking the main parameters of the monitored diesel engine, starts the generator set within the prescribed time (a few seconds) and adjusts the electrical parameters supplied by the synchronous generator according to the consumer's requirements.

The ECU (Engine Control Unit) module together with the sensor system sends information about oil pressure, coolant and oil temperature, fuel level in the tank, etc. to the AMF module. The AMF module also receives information on the current supplied

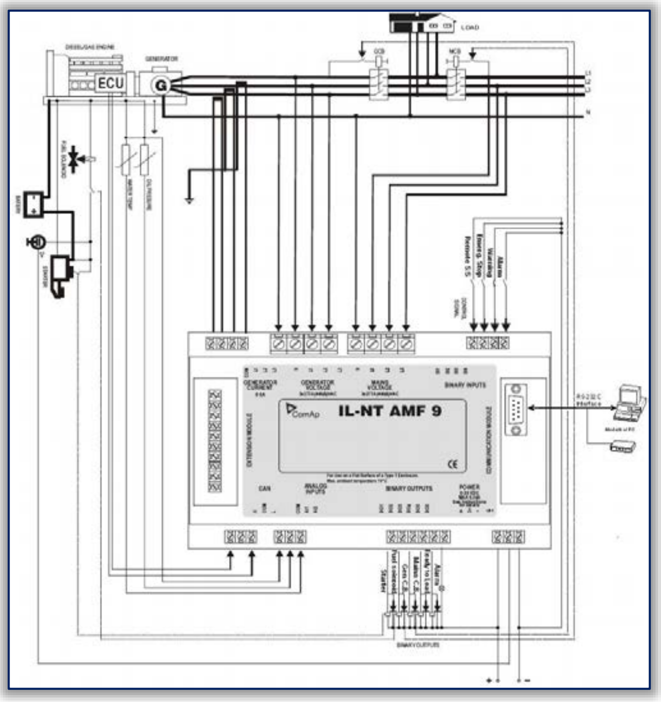

Figure 2. Schema for interconnecting a consumer with the power grid and the electric generating set

by the generator, the generator output voltage, while its parameterised setting is done using the Lite Edit software on an attached computer.
The 12/24V static battery charger charges the battery from the generator when the set is running. When it is switched off it stores electricity from the power grid keeping the battery charged at all times.
The generating set can operate either in the manual or automatic mode. If the generating set is operating in the automatic mode, the AMF 9 module detects the absence of main power grid voltage, the lower–than–nominal value or the grid asymmetry. The AMF 9 module, then, gives the command to start the generating set. The consumer connection to the generating set is done once the generating set reaches normal operation and supplies the nominal parameters If the generating set does not start, a restart command is given within 15 seconds to keep the battery charged.
The advantage of the generator set equipped with the AMF 9 module is that it allows automatic starting and stopping of the generator set, it ensures the required output parameter values, as well as generator and consumer protection, affordability.
Following the operation analysis of the generator set equipped with the AMF 9 module, observing the customer requests, the following possibilities for optimising the automation panel were identified:

≡ replacement of the AMF 9 module with another module allowing remote control/monitoring/diagnosis of the generating set;
≡ introduction of a heating system capable of removing condensate from the automation panel;
≡ redesigning the automation panel housing to provide better mechanical strength and shock protection.

These requirements can be met by a different configuration of the generator set automation panel.

3. THE ELECTRIC GENERATOR SET WITH AN OPTIMIZED AUTOMATION PANEL

Several types of modules have been analysed for the remote control and monitoring of the generator set. We chose the AMF 25, a state–of–the–art module with the following advantages:

≡ it allows remote control, monitoring, and diagnosis of the generating set via the built–in CM–GPRS (ComAp Module – General Packet Radio Service) controller, with internet access and SMS messaging functionality, via a phone SIM card compatible with IN–LT AMF 25. The CM–GPRS controller is easy to install and reliable;
≡ allows communication with the WebSupervisor internet monitoring and control platform;
≡ allows system control and error warning via SMS.

Figure 3 shows the display window of the WebSupervisor platform, which allows setting and configuring the generator set. Figure 4 shows the AMF 25 module user interface and Figure 5 shows the schematic diagram of the automation panel with the AMF 25 module.

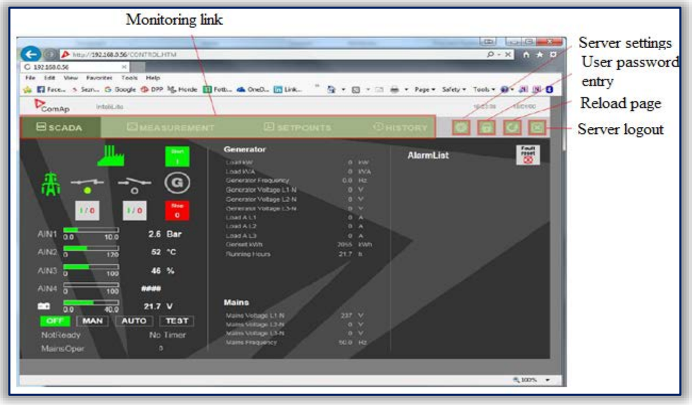

Figure 3. Websupervisor display (browser) window

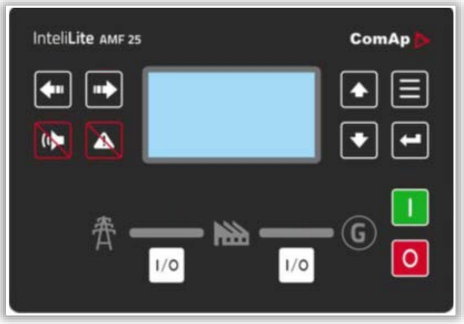

Figure 4. AMF 25 user interface

The AMF 25 module also contains several capacitors that allow it to operate when the voltage supplied by the battery pack drops below 8V.
To increase the mechanical resistance of the casing, a metal plate sheet with a 2 mm thickness was used to replace the 1 mm thick metal plate, and to eliminate the condensation that appears inside the automation panel during the cold season. Additionally, a 30 W heater that is controlled and monitored by a thermostat with a temperature setting range of 0–60 °C, was also installed. This ensures that there is a constant temperature of at least 20 °C within the automation panel, eliminating, thus, condensation.
The first step in configuring the AMF module was to set the controller input and output terminals according to the analogue or digital signals, received or supplied, and to the state of the contacts (Figure 6). After this first configuration step, we configured the variation ranges for the quantities monitored by the sensors. For example, in the case analysed by us, the maximum pressure of 10 bar was set for the oil sensor and the minimum pressure

at which the acoustic alarm should sound was set at 1.5 bar, the minimum pressure at which the automatic engine should stop was set at 1 bar, and the time delay to 3 seconds (Figure 7).

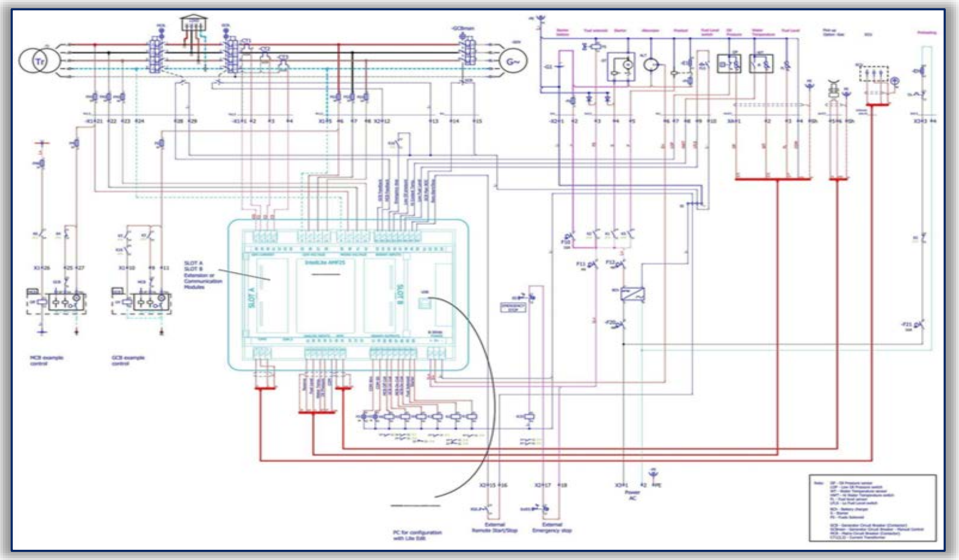

Figure 5. Automation panel schema for the electric generating set

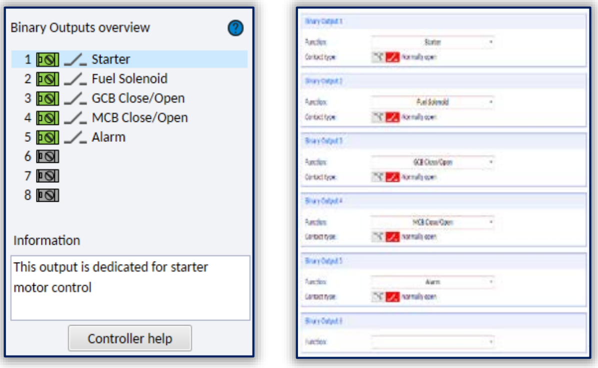

Figure 6. Output terminal configuration for the AMF controller

Figure 7. Oil sensor configuration with the AMF controller

To configure the generator we entered the values to be supplied by it: output power, rated current, transformation ratio of the phase current measuring transformers, phase and line voltages, voltage variation level, frequency, speed, and connection type (Figure 8).

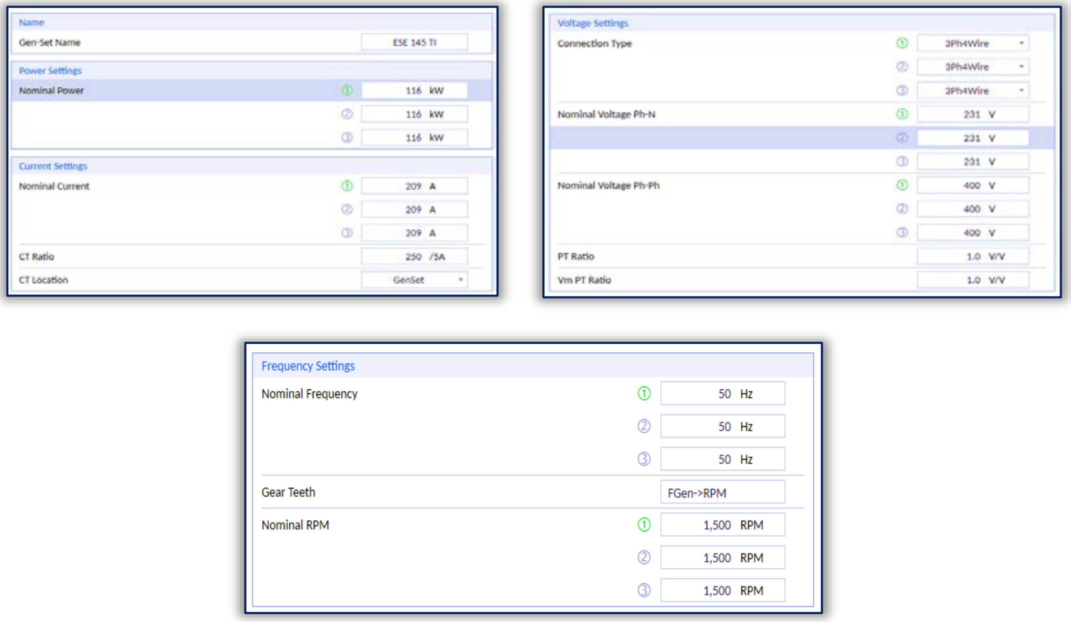

Figure 8. Electric generating set configuration with the AMF controller

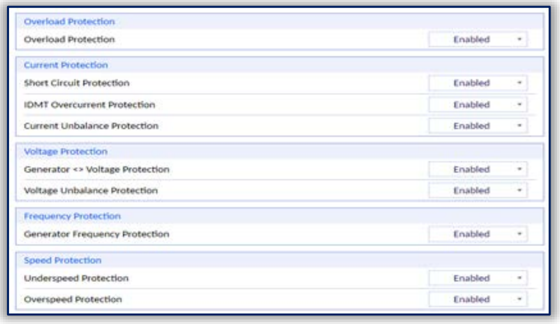

Figure 9. Electric generator set protection configuration

Figure 10. Electric generating set

For proper operation of the generating set, after every 250 hours of operation a maintenance is required, regardless of the operating mode. For this purpose we also set a maintenance warning alarm.

Furthermore, to protect the generator set we must also set: an overload protection, a short–circuit protection, an overcurrent protection, protection against current variations (unbalance), over– and under–voltage protection, a protection against unbalanced voltage, a generator frequency protection, an over– and under–speed protection (Figure 9).

Remote control of the generating set is achieved by configuring the connection to it and assigning it a name. Figure 10 shows the generating set (145 kVA, 1500 rpm) with the optimised automation panel, on which we analysed its performance.

To analyse the generating set's operation we first performed an idle run test, with a 1505 rpm speed, during which time we checked the oil pressure, the coolant temperature, and fuel level (Figure 11).

After connecting the consumers we checked the supplied voltages and power values, the supplied voltage frequency, the power factor (Figure 12), and the current values per phase. We tested the remote SMS control of the generating set by sending text messages, checking the manual operation mode, the automatic mode, the test mode, and the shutdown mode (Figure 13).

Figure 11. Speed at idle run and the protection checks

Figure 12. Electric parameters supplied by the generating set

Figure 13. SMS command messages for remote control, and remote command execution

The remote monitoring of set operation was done through the WebSupervisor platform (Figure 14) and the SCADA application on the mobile phone (Figure 15).

Figure 14. WebSupervisor browser window

Figure 15. SCADA monitoring application

4. CONCLUSIONS

The optimization of the electric generating set automation panel has shown to improve the generator's efficiency, where the replacement of the AMF 9 module with the AMF 25 module allowed controlling the generator via SMS, allowed to remotely monitor and control its operation via the WebSupervisor platform and SCADA application.

This optimisation allows an analysis of the operating mode, of the eventual faults and defects, so that diagnostics can be carried out quickly, making remote assistance to the on–site personnel using the generating set within easy reach.

Replacing the automation panel increases the mechanical resistance of the generator, while the introduction of a heating system helps to eliminate condensation and increase the service life of the components mounted in the panel.

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