

Development of ECOWILL PLUS Micro-cogeneration Unit with Autonomous Operation Function for Generating Electricity during Power Outages

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ABSTRACT

A micro combined heat and power generation (micro-cogeneration) unit for residential use has been developed that can be used during power outages by manually starting a gas engine. This unit is equipped with a recoil starter as a device that enables starting without a battery or other auxiliary power during power outages. Start control for autonomous operation was established to enable engine start by recoil. In addition, currently sold cogeneration units output at 200 V in order to connect with the grid power, but the developed unit also has a dedicated 100 V output terminal for autonomous operation so that the generated power output from the unit can be used directly by electrical equipment during autonomous operation.

These technologies enabled development of a micro-cogeneration unit with autonomous operation function for generating electricity during power outages that maintains the same size and performance of currently sold micro-cogeneration units.

1. Introduction

Combined heat and power generation systems use a generator to generate electricity, and also recover and use the heat produced by the power generation process. These systems are viewed as an effective means of reducing CO₂ emissions, and have been widely used for some time centering on large-scale private industrial power generating facilities that also serve as heat sources.

Figure 1 shows an image of installation of a combined heat and power generation system for residential use in Japan.

Honda applied its engine and inverter generator technologies developed for power products, and released a micro combined heat and power generation unit (hereafter, micro-cogeneration unit) for residential use within Japan in 2003⁽¹⁾. This was followed by the release of a second-generation model in 2006, and a third-generation model (hereafter, 2011 model year unit) that employs an extended expansion linkage engine (EXlink) to achieve even higher efficiency and a more compact size in 2011⁽²⁾.

Since the Great East Japan Earthquake, Japan has experienced planned power outages and also a number of

large-scale power outages due to natural disasters. As a result, the need has increased for equipment that supports power outages in Japan.

This paper introduces a micro-cogeneration unit for residential use with autonomous operation function for generating electricity during power outages. This is the ECOWILL PLUS configuration that adds a recoil starter function to the 2011 model year unit. Figure 2 shows an external view of the ECOWILL PLUS. (ECOWILL PLUS is a registered trademark of Osaka Gas Co., Ltd.)

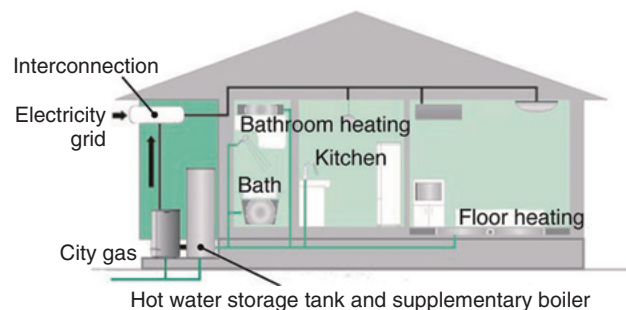


Fig. 1 General view of micro-cogeneration system

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Fig. 2 Micro-cogeneration unit with autonomous operation function for generating electricity during power outages

2. Development Goals

When developing the new unit, the goal was to add a starter function for autonomous operation with the minimum changes while maintaining the same size and performance as the 2011 model year unit currently being mass produced. Therefore, specifications were created that maintain the same normal operation performance as the 2011 model year unit, and also enable manual starting so that autonomous operation can be started to reliably supply electricity during power outages. In addition, the unit is connected to the grid power (commercial power), so single-phase 3-wire AC 100 V / 200 V is output during normal operation. However, the electrical equipment assumed to be used during power outages is AC 100 V, so single-phase 2-wire AC 100 V is output⁽³⁾.

3. Main Specifications and Features

3.1. System Configuration and Specifications

Figure 3 shows the structure of the newly developed micro-cogeneration unit, and Table 1 lists the main specifications.

Compared to the 2011 model year unit, the developed unit features a recoil starter and a dedicated output terminal for autonomous operation (maximum output 980 VA).

3.2. Starting Method during Power Outages

Micro-cogeneration units require external power to start up the starter motor when starting the engine. In contrast, the engine must be started without external power in order to perform autonomous operation for generating electricity during power outages. Therefore, possible starting devices during power outages include the following.

- A recoil starter such as often used in general-purpose engines

Table 1 Specifications

Output	Electricity	Grid connection	1000 W
		Autonomous operation	980 VA
		Heat	2500 W
Heat recovery			75°C hot water
Efficiencies (LHV)	Electricity		26.30%
	Heat		65.70%
Dimensions (L × W × H)			580 mm × 298 mm × 750 mm
Mass			76.0 kg
Noise	Grid connection		43 dB(A) / 1 m (JIS B 8627-1)
	Autonomous operation		47 dB(A) / 1 m (JIS B 8627-1)
Starting system	Grid connection		Starter generator
	Autonomous operation		Recoil starter
Engine	Type		GFV110 (EXlink)
	Displacement (Comp./Exh.)		110 cm³ / 163 cm³

Table 2 Comparison list

Item	Recoil starter	Starter motor	Starter generator
Power source	None (Manual)	Battery	Battery
Usability	Good	Good	Good
Mass-production experience	Good general purpose engine	Good general purpose engine	Good cogeneration unit
Installation ability	Fair Need operating space	Good	Good
Maintainability	Good	Fair Must replace battery	Fair Must replace battery
Layout feasibility	Good	Fair Need additional space	Fair Need additional space
Conformity to regulation	Good	Good	Good

- A kick-type starter such as used in motorcycles
- A starter motor with a battery such as used in automobiles
- A starter generator with a battery

In consideration of applicability to engine start, the recoil starter and the two methods that use batteries were compared. Table 2 shows the results, and ultimately the recoil starter was selected.

The 2011 model year unit was a more compact unit with little space around the engine, so it was a challenge

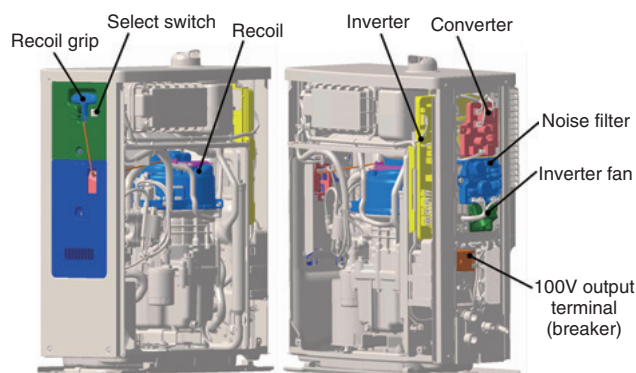


Fig. 3 Structure of micro-cogeneration unit

to mount a recoil starter such as used in general-purpose engines. Therefore, attention was turned to the cooling fan located on top of the alternator, and a new cooling fan and fan cover were developed and integrated with a recoil starter. This enabled mounting of a recoil starter without impairing the cooling function (Fig. 4).

In the recoil operation elements, the recoil grip is stored in the operation panel and protected by the switch panel cover to help prevent noise leaking from inside the engine room via the rope guide and to help prevent mishandling and tampering (Fig. 5).

3.3. Inverter for Autonomous Operation

The inverter of the current model connected to the grid power performs single-phase 3-wire AC 200 V output. However, when generating power by autonomous operation, both a grid connection output terminal and a separate dedicated output terminal are required to obtain domestic certification⁽⁴⁾. In addition, when performing autonomous operation, a dedicated inverter is required to produce high-quality AC 100 V output that can be used by general

electric appliances at the dedicated outlet.

An inverter was therefore developed that enables both grid connection output and autonomous output. Also, when performing AC 100 V output, the current value is approximately twice that during normal operation, so the amount of heat generated by the surface-mounted devices on the inverter increases. For this reason, a compact electric fan that operates to cool the inverter only during autonomous operation was adopted.

3.4. Flow of Electricity during Autonomous Operation

Power needs to be supplied from a dedicated output terminal during autonomous operation, so recoil starting is performed after switching the plug of the hot water storage tank from the outlet for grid connection operation to the outlet for autonomous operation during power outages (Fig. 6).

Figure 7 shows the flow of electricity during normal operation and during power outages.

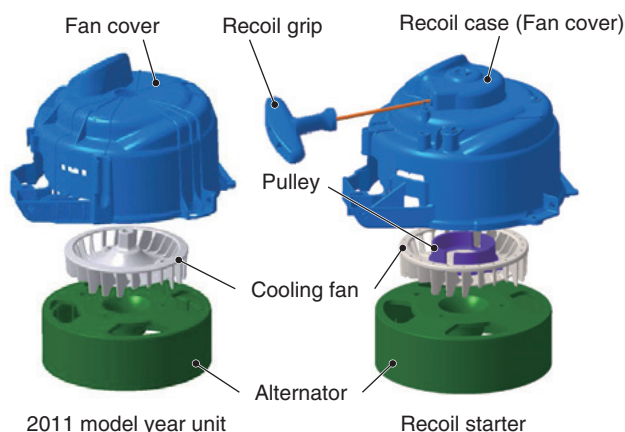


Fig. 4 Recoil starter

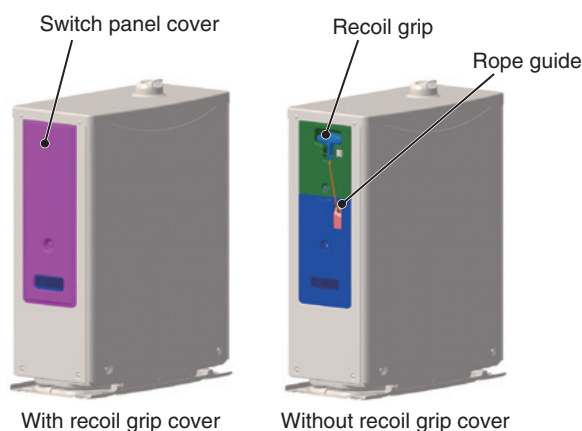


Fig. 5 Position of recoil grip

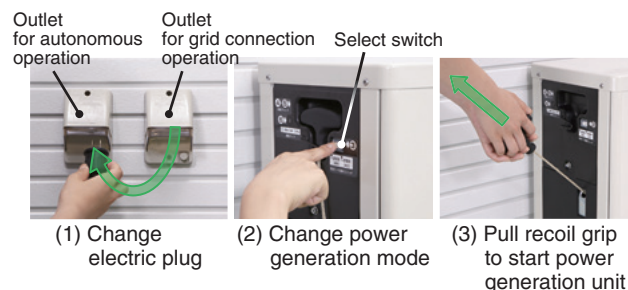


Fig. 6 Starting procedure

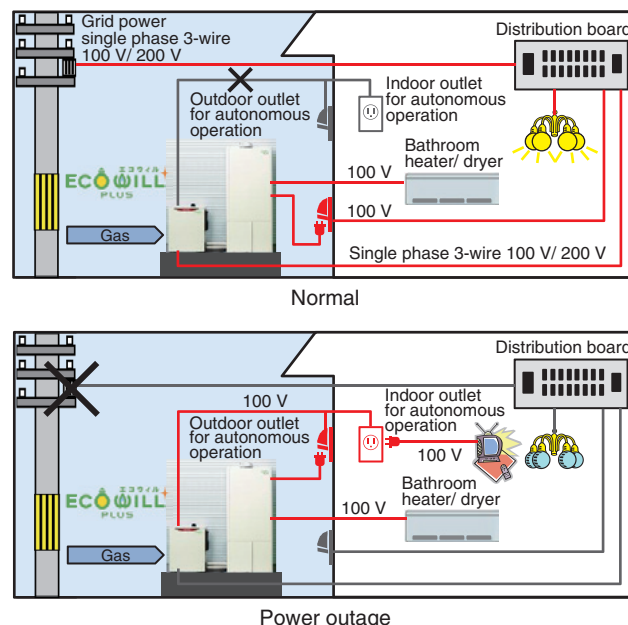


Fig. 7 Flow of electricity

4. Key Technologies

4.1. Recoil Starter

4.1.1. Required performance

The items required of the recoil starter are as follows.

- Durability in an engine room internal temperature (approximately 80°C) environment
- Able to be pulled even by someone operating the recoil starter for the first time

4.1.2. Method of achievement

The operating load and the rotating speed, that is to say the rope stroke, are conflicting requirements. However, due to the goals of this development, it was necessary to add a recoil starter function without changing the size of the enclosure. Therefore, the maximum pulley diameter that can be housed inside the cooling fan without impairing the engine cooling function was investigated. The flow of the cooling wind was analyzed (Fig. 8), and the results showed that the optimal maximum pulley diameter was 75 mm. This was then checked using an actual unit, and the results confirmed that equivalent cooling performance could be obtained. This enabled positioning a reel for winding the rope on top of the cooling fan (Fig. 9). The space required to perform the starting operation for autonomous operation was set at 1500 mm based on the installation conditions in the typical operating environment, so the reel diameter

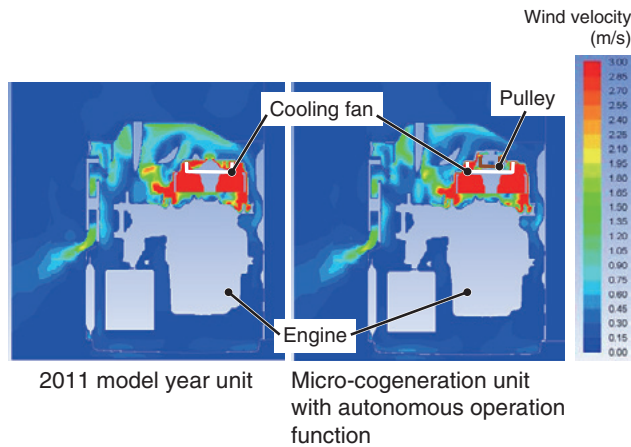


Fig. 8 Flow analysis of cooling wind

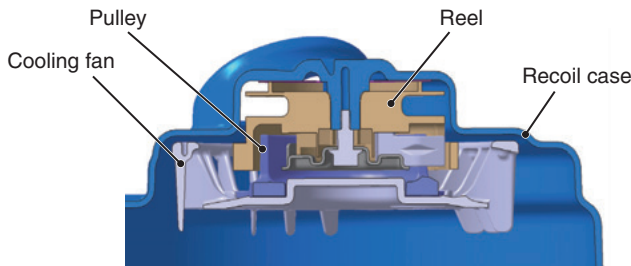


Fig. 9 Structure of recoil

was set at 46 mm. This resulted in a required operating load around the 400-N, which is equivalent to the operating load required for a 400 cm³ class general-purpose engine. In addition, the operating load was reduced by employing a large recoil grip and enhancing operability. Furthermore, the optimum rope pulling direction was derived using human models with 3D data, and the rope outlet shape was designed to reduce rope wear and other issues (Fig. 10).

In consideration of high-temperature degradation characteristics and durability, this development used aramid fiber rope as the recoil rope material instead of the nylon fiber rope used in many general-purpose engines. In addition, the boss of the recoil case that supports the reel receives a large load during the recoil operation. Therefore, strength at high temperatures and long-term durability were secured by making the aluminum recoil case.

4.2. Start Control for Autonomous Operation

4.2.1. Required performance

Conventional starting used the commercial power supply, and this power was sufficient for ignition. In contrast, during autonomous operation it is necessary to provide the number of ignition times required for engine start by supplying the power required to ignite the spark plugs to the ignition coil for approximately 1 second while the engine is rotating by recoil starting (Fig. 11).

4.2.2. Method of achievement

As mentioned above, it is necessary to provide the number of ignition times required for reliable engine start, so the ECU that controls ignition needed to be started quickly. In addition, it was also necessary to secure stable control power supply in order to provide the required number of ignition times. Therefore, a boost converter was positioned upstream of the ECU (Fig. 12). The boost converter functions when the engine speed exceeds 550 rpm as shown in Fig. 13. As a result, the ECU starts quickly and the ignition-enabled voltage period is lengthened, providing the number of ignition times required for engine start.

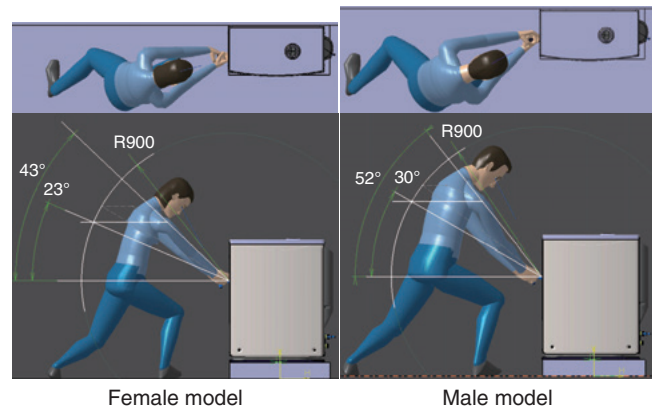


Fig. 10 Human model layout

4.3. Autonomous Operation Control

4.3.1. Required performance

Autonomous operation control requires the certification issue described in section 3.3. and also functions to protect the system against overload.

4.3.2. Method of achievement

Separate circuits were established for grid connection output and autonomous output. Then relays and inter-lock

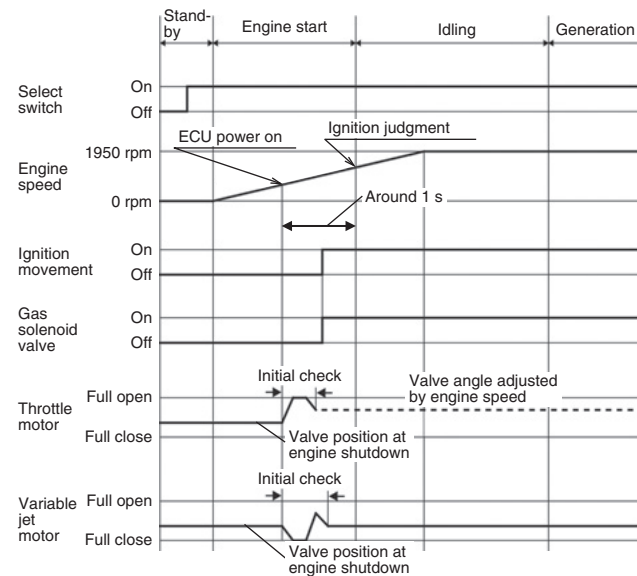


Fig. 11 Starting sequence of autonomous operation

circuits for each output were provided on the circuit board to help prevent incorrect output. Figure 14 shows the block diagram.

In addition to the grid connection protective functions, dedicated protective functions for autonomous operation were added to protect against momentary overload that may occur during autonomous operation, or cases where the output rises gradually until it exceeds the maximum output. These functions operate to protect against low engine speed and momentary overload in the event of overload operation, and the engine is stopped when any of the protective functions has operated. The unit can be used again by disconnecting some of the electrical appliances connected to the outlet to reduce the load and then restarting the engine.

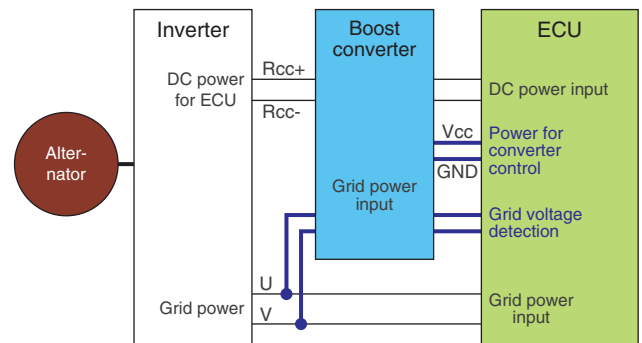


Fig. 12 Diagram of converter

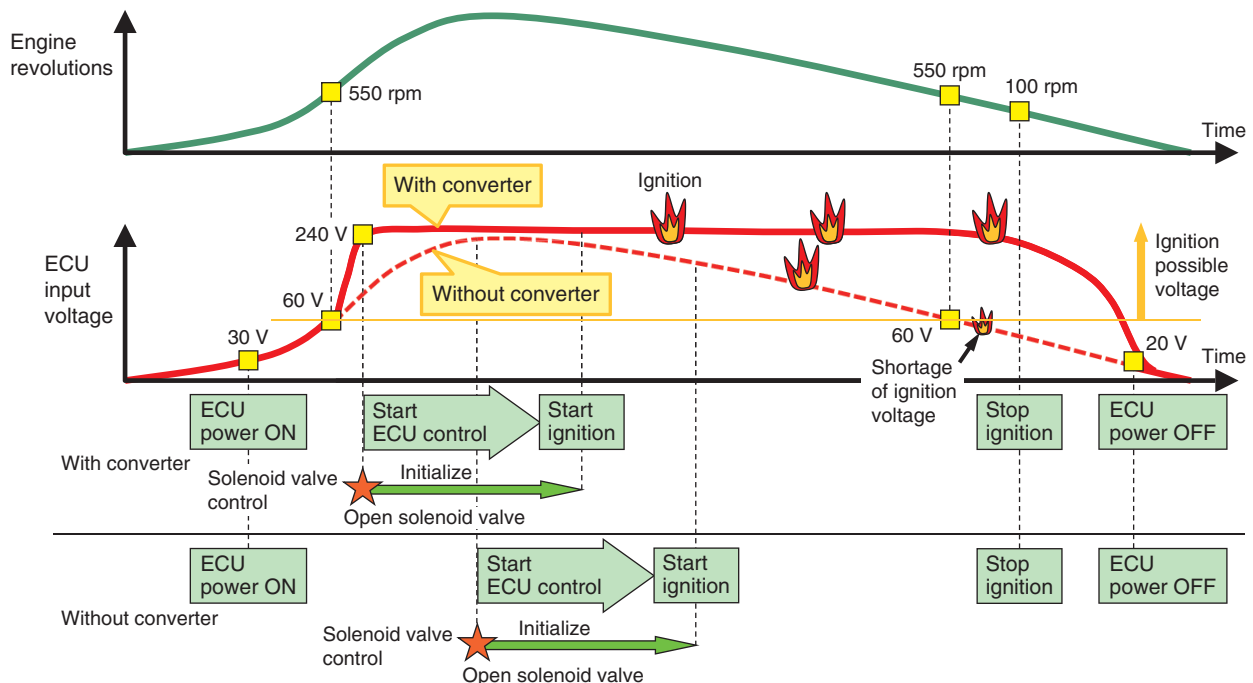


Fig. 13 Ignition timing

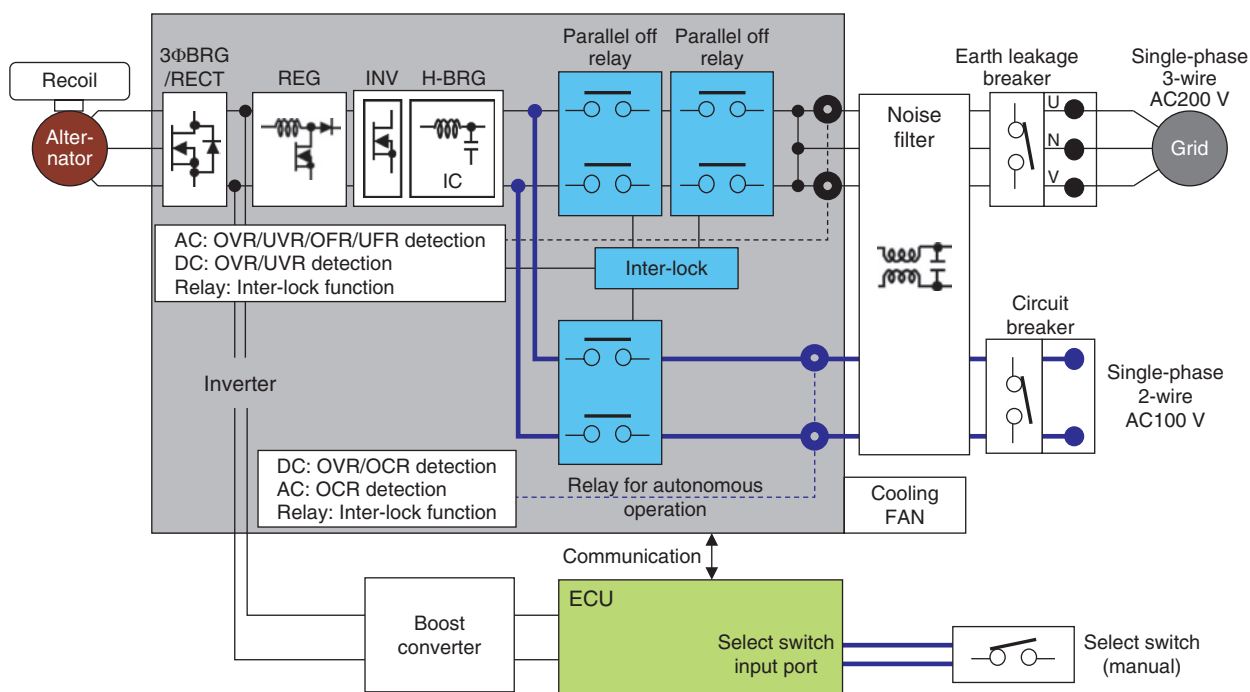


Fig. 14 Cogeneration unit block diagram

5. Conclusion

A micro-cogeneration unit for residential use that is capable of autonomous operation for generating electricity during power outages was developed that maintains the same size and high performance of the 2011 model year unit.

- (1) A recoil starter with the durability to enable use whenever necessary was added. The operation load was set to enable starting even by someone operating the recoil starter for the first time, and start control for autonomous operation was established that enables reliable engine start.
- (2) The use of Honda's inverter generator technology enabled supply of high-quality power so that electrical appliances with total power consumption of 980 VA or less can be used, even during autonomous operation.

References

- (1) Takaishi, T., Ara, M., Togawa, K.: Introduction of Micro Combined Heat and Power Generation Unit for Residential Use, Honda R&D Technical Review, Vol. 15, No. 1, p. 53-58
- (2) Takita, Y., Kono, S., Takada, H., Kitsu, K., Naoi, A., Tsuno, K.: Development of Micro Combined Heat and Power Generation Unit with Extended Expansion Linkage Engine, Honda R&D Technical Review, Vol. 23, No. 2, p. 30-38
- (3) <http://www.honda.co.jp/cogeneration/ecowillplus/>

- (4) Grid-connected Inverters (Power conditioners) for small distributed generation systems, Japan Electrical Safety & Environment Technology Laboratories (JET): <http://www.jet.or.jp/en/products/protection/index.html>

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