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EMERGENCY POWER SUPPLY VEHICLE FOR DISTRIBUTION SERVICE

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I. INTRODUCTION

The demand for electric power in Japan has grown rapidly in recent years, along with economic growth and development. The degree of dependence on power has risen due to the concentration of the population in urban and suburban areas, the construction of skyscrapers as part of urban redevelopment, the mechanization of all types of equipment in the large cities, the increased scale of production and the popularity of electric appliance in ordinary homes as the standard of living improves. In keeping with this, the demands for improved power quality are also on the increase.

In order to meet these requirements, investigations are now underway in various sectors to find rational and complete solutions by means not only of former techniques and expansions of those techniques, but also by new techniques in the field of power distribution which includes a major part of power carrying equipment and faces such problems as harmony with the environment, the shortage of manpower and the lack of land. The results of this research and development are now being put into practical use and are expected to prove highly effective. In accordance with these efforts, Fuji Electric is now carrying out research and development on several pieces of distribution equipment. One of these is the emergency power supply vehicle for 50 kVA distribution which was delivered to the Tohoku Electric Power Co., Inc. A series of these vehicles has been completed and they are outlined in this article.

II. REQUIRED CONDITIONS

Since equipment for power distribution is almost always used on land, there are many social limitations applied to such equipment and therefore, there are many requirements imposed on the distribution equipment in accordance with the particular chracteristics of the region in which it is used. The main requirements needed in emergency power supply vehicles are as follows:

1) They must be compact and light in weight.
2) Driving and operation must not require special lisences or techniques.
3) The required tools and protective equipment for connection cables, lighting equipment, etc. must be provided.
4) The vehicle engine and the generator engine should be made by the same manufacturer so that they can be provided for simultaneously. They should also use the same fuel.
5) They must run well even on bad roads.
6) They must be adapted to all climates so that power can be transmitted in winds, rain, etc.
7) They must be capable of being operated as long as possible.
8) They must be work with unbalanced loads.
9) The noise must be as low as possible.
10) Parallel operation must be easy.
11) They must be in accordance with existing laws.

In addition to the above, there are naturally also certain general conditions necessary such as a low price, the possibility of applying large capacity loads momentarily, simple frequency control, and automatic operation at stable speeds.

Besides the necessity of fulfilling all of the above conditions, it is also essential to adapt all of these conditions as much as possibile to the area of use and also the aim of the equipment.

III. RATINGS

The ratings of the standard emergency power supply vehicle are given in *Table 1* for the low voltage type and *Table 2* for the high voltage type.

IV. CONSTRUCTION

Fig. 1 shows an outer view of the 50kVA emergency power supply vehicle for low voltages, and *Fig. 2* gives its construction. The construction of the 100 kVA vehicle for low voltage is shown in *Fig. 3*, while that for the 150 kVA and 250 kVA vehicle for high voltage is shown in *Fig. 4*. The construction of the 50 kVA vehicle is such that the engine unit, the generator unit and the transformer unit can be separated in order to minimize the weight when

Table 1 **Ratings of emergency power supply vehicle for low voltage**

Item	Model	TG-50L		TG-100L		TG-150L		TG-200L
AC generator	Type	CVFT176/7-4		CVFT196/14-4		CVFT 226/19-4	CVFT 196/17-4	CVFT226/19-4
	Output (kVA)	50		100		150		200
	Frequency (Hz)	50	60	50	60	50	60	60
	Rotational speed (rpm)	1,500	1,800	1,500	1,800	1,500	1,800	1,800
	Rated voltage (V)	200	220	200	220	200	220	220
	Rated current (A)	145	131	290	262	432	393	525
	Power factor (%)	80		80		80		80
	No. of poles (P)	4		4		4		4
	Phases (ϕ)	3		3		3		3
	Duty	Continuous						
	Insulation class	B		B		B		B
	Excitizing method	Static self excitation						
Engine	Type	Isuzu GD150PS		Isuzu DH100T		Nissan UDV-815	UD-635	Nissan UDV-815
	Cooling	4 cycle water cooled		4 cycle water cooled with turbocharger		2 cycle water cooled direct injection		
	No. of cylinder Bore×stroke	6-100×120		6-120×150		V8-110× 130	6-110× 130	V8-110×130
	Piston displacement (cc)	5,654		10,179		9,882	7,412	9,882
	Rating power (PS)	70		140		180		240
	Rotational speed (rpm)	1,650		1,500	1,800	1,500	1,800	1,800
	Consumption (g/PS·h)	265		190		200	210	210
	Fuel	Gasoline		Diesel fuel				
Transformer	Type	Dry type				—		—
	Output (kVA)	50		100		—		—
	Rated voltage (V)	200/200 100	220/200 100	200/200 100	220/200 100	—		—
	Phase (ϕ)	3/2		3/2		—		—
	Connection	Scott connection				—		—
Vehicle	Type	Isuzu TLG52R		Isuzu TR30R		Nissan UEG780	QC80	Nissan UEG780
	Loading capacity (t)	3		4.5		6.5	3.5	6.5
	Fuel	Gasoline		Diesel fuel				
	Max. gross weight of vehicle (kg)	5,335		7,600		9,300	6,800	9,300
	Persons	3		3		3		3

helicopter transport is required because of difficult road transport conditions. The engine and generator parts also employ the belt drive system which is very simple to assemble. Therefore, the engine part, generator part and transformer part can each be transported separately to areas where vehicles can not enter and direct operation is possible after on-site assembly of these units and addition of the drive belts. For this reason, the operation panels required for each of these units are attached separately to each part. The electric circuit for the 50 kVA model is shown in *Fig. 5*. As can be seen in each of the construction figures, the various types of load devices are arranged so that the load is applied appropriately to the axle of the vehicle and the maximum safe tilt angle of the vehicle is not exceeded regulation value.

The body is constructed of aluminium for light weight and corrosion resistance and aluminium corrugated plates are used for added strength. A ladder is attached and checkered aluminium plates to prevent slipping are used on top of the body so

Table 2 **Ratings of emergency power supply vehicle for high voltage**

Item	Model	TG-150H		TG-250H		TG-375H	TG-437.5H	TG-500H
AC generator	Type	VFT 226/17-4	VFT 266/15-4	VFT 266/19-4	VFT 266/16-4	VFT 266/25-4	VFT 266/25-4	VFT 266/29-4
	Output (kVA)	150		250		375	437.5	500
	Frequency (Hz)	50	60	50	60	50	60	50
	Rotational speed (rpm)	1,500	1,800	1,500	1,800	1,500	1,800	1,500
	Rated voltage (V)	6,000	6,600	6,000	6,600	6,000	6,600	6,000
	Rated current (A)	14.4	13.1	24.1	21.9	36.1	38.3	48.1
	Power factor (%)	80		80		80	80	80
	No. of poles (P)	4		4		4	4	4
	Phase (ϕ)	3		3		3	3	3
	Duty	Continuous						
	Insulation class	B		B		B	B	B
	Exciting method	Rotating exciter						
Engine	Type	Nissan UDV-815	Nissan UD-635	Mitsubishi 6DE10PT	Mitsubishi 12DH20P	Mitsubishi 12DH20PTA		Mitsubishi 12DE20PT
	Cooling	2 cycle water cooled direct injection		4 cycle water cooled pre-combusion chamber		4 cycle water cooled with turbocharger		
	No. of cylinder (Bore×stroke)	VS-110 ×130	6-110×130	6-150×200	V12-135× 160	V12-135×160		V12-150× 200
	Piston displacement (cc)	9,882	7,412	21,200	27,500	27,500		42,400
	Rating power (PS)	180		305	340	455	540	610
	Rotational speed (rpm)	1,500	1,800	1,500	1,800	1,500	1,800	1,500
	Fuel consump. (g/PS·h)	200	210	200	205	200		200
Vehicle	Type	UEG780	QC80	T810H		T910K		T951Q
	Loading capacity (t)	6.5	3.5	8.0		11.0		11.0
	Max. gross weight of vehicle (kg)	10,000	7,335	13,100	13,700	15,500		18,835
	Person	3		3		3		3

Fig. 1 Outer view of 50 kVA vehicle for low voltage

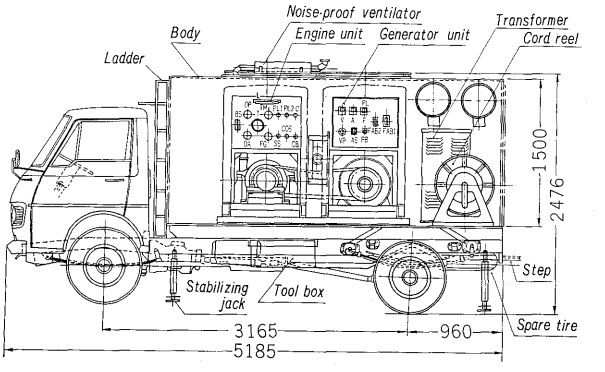


Fig. 2 Construction of 50 kVA vehicle for low voltage

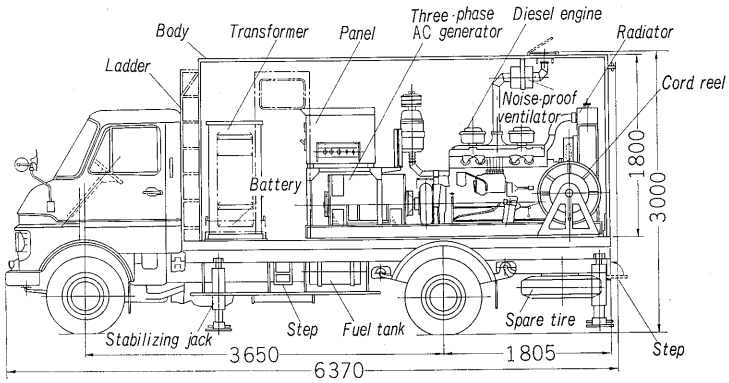
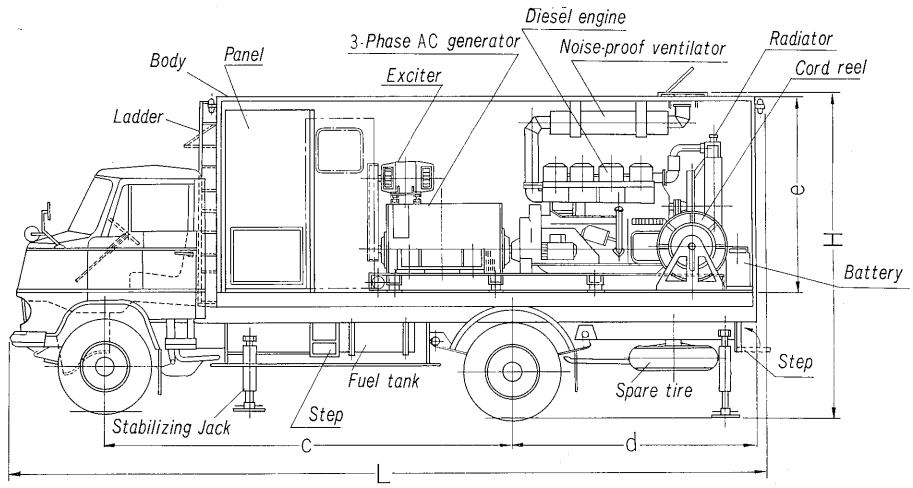
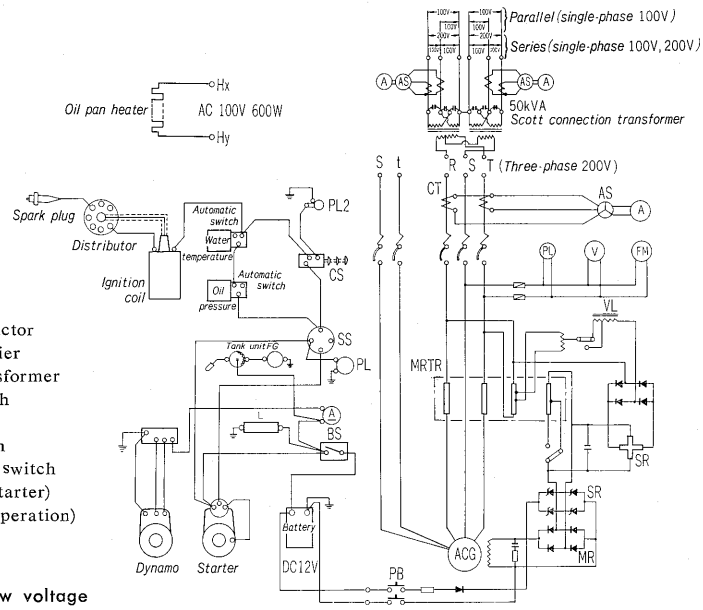


Fig. 3 **Construction of 100 kVA vehicle for low voltage**



Model	Width	L	H	c	d	e
150kVA	2,115	6,440	2,960	3,550	2,020	1,750
250kVA	2,480	8,390	3,200	4,700	2,330	1,800

Fig. 4 **Construction of 150 kVA or 250 kVA vehicle for high voltage**



ACG:	AC generator	VL:	Saturable reactor
V:	AC voltmeter	MR:	Silicon rectifier
A:	AC ammeter	CT:	Current transformer
FM:	Frequency meter	BS:	Battery switch
PL:	Pilot lamp	A:	DC ammeter
VR:	Voltage regulator	SS:	Starter switch
PB:	Push button switch	CS:	Change over switch
AS:	Ammeter switch	PL1:	Pilot lamp (starter)
MRTR:	Mutual reactor transformer	PL2:	Pilot lamp (operation)
		L:	Lamp
SR:	Saturable reactor	FG:	Fuel meter

Fig. 5 **Electric circuit of 50 kVA vehicle for low voltage**

that it is easy to get on top of the vehicle for assembly and disassembly of the noise-proof air vent etc. Inside the body, checkerd steel plates are also used as linings in the parts through which the vent passes. In order to prevent noise, a package system employing glass-wool sound-proofing material is used for both the engine and the generator and the body is also lined with sound-proofing material. A noise proof ventilator is also arranged in the engine air duct. In order to eliminate vibration-proof rubber is provided under the beds of the engine and the generator. Since the engine, etc. is in the vehicle, a load is ordinarily applied. Thus, the vehicle is provided with a stability jack to protect the axle

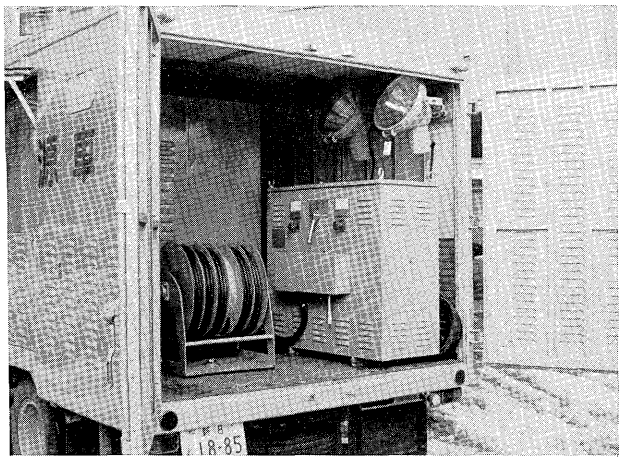


Fig. 6 Inner view of 50 kVA vehicle for low voltage

spring during storage or long periods of generation, a generation indicator lamp which is lit during operation, a battery (110 AH DC 12 V) for the control circuit and starting, two lighting devices (AC 100 V 500 W) for night operation, a power source for the lighting equipment, a receptacle (single phase AC 100 V 3 kVA) for the machine tools, a drawer for the connection cables rotary type cord reals convenient for retracting and grounding wire. *Fig. 6* shows an inner view of the low voltage vehicle with the rear door open.

In addition, the accessories usually provided in a vehicle and one set of equipment required for driving and operation of the engine and generator are included.

V. PLANNING PRECAUTIONS

There are several precautions which must be taken into account when planning and designing emergency power supply vehicles.

1) Generator capacity and voltage

It is recommended that the generator capacity be as possible but actually it must conform with certain conflicting limitations such as the permissible vehicle load capacity. However, considering the aim of application, it is considered sufficient if the power is supplied within the supply region of a pole mounted transformer in the case of low voltages (100 and 200 V) and if emergency supplies for hospitals and lighting failures during disasters, as well as stable power for customers requiring high voltages can be maintained. The average unit capacity for existing pole mounted transformers of the power companies in Japan is 14.4 kVA but there is a tendency to increase these capacities and 50 and 75 kVA are now being used. The power required in the latter case will be 50 kVA. Therefore, in the case of low voltage models, it can be considered that it will be sufficient if the capacity is 50 or 100 kVA but 150 and 200 kVA is also standard for 3-phase power. In the case of buildings, there will also be times when the rated voltage will have to be 400 V. In the case of high voltage (3 kV or 6 kV) models, it is impossible to provide a capacity suitable for the permissible distribution capacities (2,000 to 3,000kVA) of 6 kV distribution lines but since separation switches are used in the distribution lines, it can be considered sufficient if the power supplied to the loads required in these separated areas is used. When dividing the total capacity of existing pole-mounted transformers in Japan by the total number of sectional switches, the value becomes about 100 kVA. In other words, this is the average value of the load in each section of the 6 kV distribution lines. Therefore, the standard rated capacities for high voltages are 150,250, 375,437.5 and 500 kVA. When more over capacities are required, parallel operation is considered as the best measure.

2) Drive engine

The output of the drive engine can be calculated from the following equation:

$$\text{Engine output (HP)} = \frac{\text{Generator output (kVA)} \times \text{power factor (\%)}}{\text{Generator efficiency}} \times \frac{1}{0.736}$$

The standard units are selected in consideration of ease of starting, weight, low noise, etc. Considering the overload withstand needed for the motor starting current (from several seconds to several dozen seconds) and also the particular distribution characteristics, it is desirable that overload drive over 10% for about one hour be possible. When determining the rotational speed, both the drive engine and the generator become small if the rotational speed is large, but after selecting the lowest price and most reliable unit according to standard engine output and rotational speed, the engine rotational speed can be selected in accordance with the number of the whole system.

When considering convenience of checking and arrangement, it is best if the automobile engine and the generator drive engine are made by the same manufacturer. Engines should also be selected which use the same fuel. Since this vehicle is used for emergencies when circulation cooling, which requires cooling water such as industrial water, river water or well water, can not be used, many details must be considered.

3) Transformer

For low voltage distribution lines used in Japan, there are two standard types: the 100 V single phase 2-wire type used for supply of lighting loads and the 200 V 3-phase 3-wire type used for power loads. However, since increasing demands are causing voltage drops and power losses in the single phase 2-wire systems, single phase 3-wire system is now more widely used.

The following cases can be considered for emergency power supply vehicles of the low voltage type which can be supplied by 3-phase 4-wire systems used for

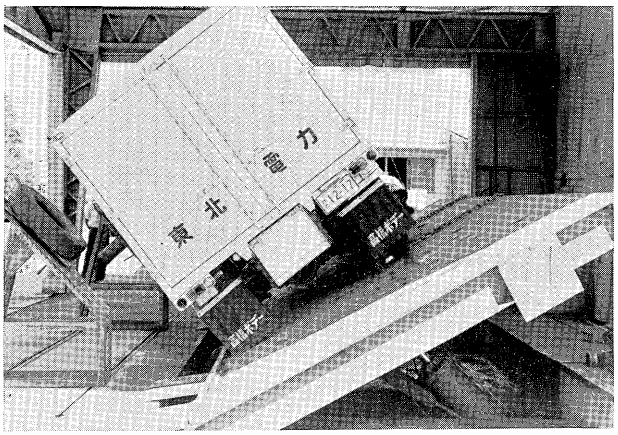


Fig. 7 Test of maximum safe angle of tilt

both lighting and power in order to minimize distribution equipment costs:

(1) 100 V single-phase 2-wire system
(2) 100 V single-phase 3-wire system
(3) 200 V three-phase 3-wire system
(4) 100/200 V three-phase 4-wire system (for both 100 V lighting and 200 V power)

Since the generator must supply 3-phase power, it is a 3-phase synchronous generator and therefore unbalanced loads must as limited as possible. When there is only a single phase load, it must be kept to below 25% of the rated current in general. Therefore, since the generator utilization rate is greatly reduced, a Scott connection transformer for 3-phase 2-phase conversion is used for single phase loads and it is necessary to improve the utilization factor of the generator.

In the case of (1) and (2) described above, the Scott-connection transformer is used and in the case of (3), it can be used directly with a generator voltage of 200 V. In the case of (4), the transformer can be used with the V-connection or a delta connection transformer of a different capacity can be used. When high voltages are used, the 6 kV distribution line can be considered as almost the same as a 3-phase balanced load, and therefore, if the rated voltage of the 3-phase synchronous generator is 6 kV, direct supply is possible and it is not necessary to think of it the same way as in the case of low voltage.

4) Vehicle

After the weights and dimensions of the load materials such as the engine, generator and transformer are decided, the vehicle is chosen, but when making this selection, it is best to choose from standard types of vehicles by stressing a low center of gravity, the same maker as the generator drive engine and economy. It is especially necessary that the vehicle meets the standards for weight distribution of the loaded objects and the maximum safe angle of tilt. *Fig. 7* shows the vehicle undergoing a test for the maximum safe angle of tilt. It is best that the steering angle be small so that the vehicle is easy to drive, the overall height be as low as possible and other details be considered carefully.

5) Others

A distribution panel is needed for the meters and control devices required for generator operation, excitation adjustment equipment, control devices needed for control of starting, stopping and operation of the generator drive engine, etc. The arrangement of these control systems and devices must allow for emergency starting, one man control, etc.

Other protective devices do not require any special considerations and no special equipment should be needed for the emergency vehicle. Emergency vehicles for high voltages require a high voltage circuit breaker but this breaker can be ordinary type as long as it is small, light weight and vibration resistant. When parallel generator operation is carried out, a synchronous setting panel is also needed.

VI. CONCLUSION

This article has outlined Fuji's emergency power supply vehicles. In the distribution field as in all other fields, the manpower shortage is becoming more and more acute and labor saving measures.

Therefore, we respect the opinions of the users who are actually using the equipment and the equipment will be more easy to use, will be more suitable for the application aims and location for this reason, the opinions of customers are greatly appreciated. In conclusion, the authors wish to thank sincerely all those in the Tohoku Electric Power Co., Inc., who aided in the manufacture of this emergency power supply vehicle.