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Research paper

A Study on High Performance Generator Transfer System with Grid Connection and UPS

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Abstract

Background/Objectives: Recently, the safety of the grid has been deteriorated due to the increase of the equipment using the stationary power converter, and the system accident such as power outage is increasing. Therefore, in recent years, there has been a surge in demand for systems that can supply stable power even if system accidents occur.
Methods/Statistical analysis: The virtual coordinate conversion value obtained by converting the generator voltage to the rotational coordinate system based on the phase angle information based on the UPS voltage is obtained for linking the emergency generator with high accuracy. Then, it controls the Gabon and AVR of the generator to estimate the d-q voltage on the rotating coordinate system based on the phase angle information based on the UPS voltage. Therefore, when the d-axis component on the virtual rotation coordinate system is controlled to be 0, the generator voltage frequency becomes equal to the grid voltage frequency. If the q-axis component of the virtual rotation coordinate system is controlled by the q-axis voltage of the system rotation coordinate system, the generator voltage and the grid voltage become equal. To detect the switching point, I have improved the degree of voltage detection using a method of detecting the difference in magnitude and phase difference between different power sources. In order to compensate the fluctuation of the generator frequency when the load of the stand-alone generator suddenly changes, an algorithm that detects the active power instantaneously and performs feedforward control using it is applied.
Findings: The proposed algorithm improves the voltage detection accuracy by detecting the difference of the dissimilar power source in order to detect the size and the phase difference to a high degree in the dissimilar power source. In addition, after controlling the d-axis voltage of the rotating coordinate system to 0, CTTS was injected to drastically reduce the inrush current. When the CTTS were shut off, the zero-current implementation through the instantaneous effective and reactive power control enabled us to stabilize the no arc and the system.
Improvements/Applications: It has also been found that this system can be used not only as a UPS, but also as a reactive power compensator for system voltage stabilization.

Keywords: *CTTS, ATS, Stable transfer, Diesel-engine generator, zero power control*

1. Introduction

Recently, as global warming and environmental pollution problems caused by fossil fuels have become global issues, interest in renewable energy sources is increasing. Renewable energy sources are adversely affecting the Grid due to the sudden change of the current due to the irregularity of the output. Also, as the modern society develops, the rectifier load is increasing in high performance industrial equipments and household appliances. Load using such a static power converter is another factor of lowering the grid stability due to the discontinuous current.[1-3].

Due to irregular power sources such as renewable energy sources, and the increase of equipment using static power converters, the safety of the grid is decreasing, and grid accidents such as power outages are increasing. Accordingly, research has been actively conducted on a system capable of supplying stable power even when a grid accident occurs. Generally, a grid switching system using a dual grid is being built in a large capacity receiving facility and an UPS(uninterruptible power supply) system is being built in a medium and small capacity receiving system. However, a UPS system combining a battery and a stationary power converter is required to build a large-capacity battery system in order to cope with a grid failure such as a long-time power failure. Such a large-capacity battery construction is a major cause of the increase in the system unit price, and the dissemination is not activated. Hybrid UPSs combined with existing generators are emerging as an alternative to reduce the battery that accounts for most of the UPS system unit cost. In a hybrid UPS system, the battery supplies power only during generator start-up if a power outage occurs, and the generator supplies power after the generator voltage stabilizes. Such a system reduces system cost by minimizing the capacity of the battery. In this system, CTTS (Closed Transition Transfer Switch) is a CTTS that switches to a finite source inverter, unlike a conventional CTTS that is switched to a grid considered as an infinite source[4,5]. To switch a system using an existing CTTS, you must enter it at the same time when the different power sources are the same size and phase. However, since it is difficult to implement, in practice, a large inrush current occurs due to input at a point within a prescribed size and phase error. In particular, the stability of the system is severely affected when switching between a generator and a finite source inverter in a hybrid system. Therefore, stricter injection regulations than the

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existing CTTS rules are urgently needed to stabilize the system. In addition, when the CTTS is shut off while the power is supplied from the generator, the aging due to the current causes the CTTS contact aging to progress rapidly, shortening the life span and adversely affecting the grid stability due to the abrupt load change.[6,7].

In this paper, we propose a new CTTS algorithm that can apply zero power injection and zero current cutoff for hybrid systems. The proposed algorithm improves the voltage detection accuracy by detecting the difference of the dissimilar power source in order to detect the size and the phase difference to a high degree in the dissimilar power source. In addition, after controlling the d-axis voltage of the rotating coordinate system to 0, CTTS was injected to drastically reduce the inrush current. When the CTTS were shut off, the zero-current implementation through the instantaneous effective and reactive power control enabled us to stabilize the no arc and the system. It has also been found that this system can be used not only as a UPS, but also as a reactive power compensator for system voltage stabilization.

2. CTTS for Grid Switching

2.1. Existing CTTS System

Most uninterruptible systems using generic emergency generators are constructed using ATS. This method has been found to malfunction on most control boards in installed systems due to the drawback of momentary power failure. As demand for CTTS increases at present, some systems are adopting this method as shown in figure 1.

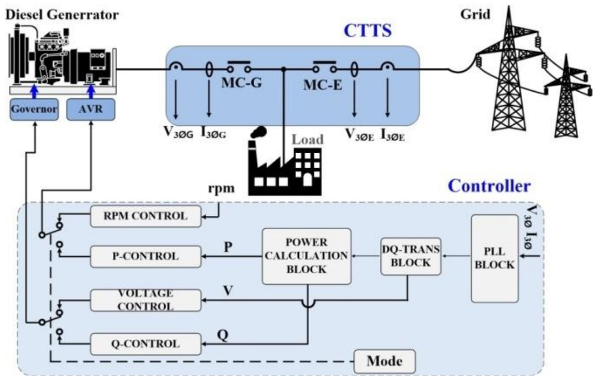


Figure 1: Existing CTTS system

In the uninterruptible power supply system using the CTTS, there is a short time in which MC-G and MC-E are simultaneously supplied for uninterruption in switching. In this case, as well as a large inrush current, the CTTS is shortened in life due to the large arc in switching, and the CTTS supply is limited due to the high switching cost. Even if an uninterruptible power supply system using CTTS is deployed, it is possible to operate the uninterruptible power system during the predicted power failure period, but it cannot operate as an uninterruptible power system in the event of an unexpected power failure. Therefore, a power outage cannot be avoided for a couple of minutes during which the emergency generator starts and the voltage frequency of the generator is stabilized in the event of an unexpected power failure. However, current use of critical power load devices such as automation equipment is increasing, and in order to maintain uninterruptible power even during unexpected power outage, a system that can supply power to the load uninterruptedly for a short time that the generator starts and stabilizes It is essential. It is essential to build an uninterruptible power system in this system combined with a short-term UPS, but only for some because of the high cost of the battery and the power converter[8-10].

2.2. The Proposed Hybrid CTTS System

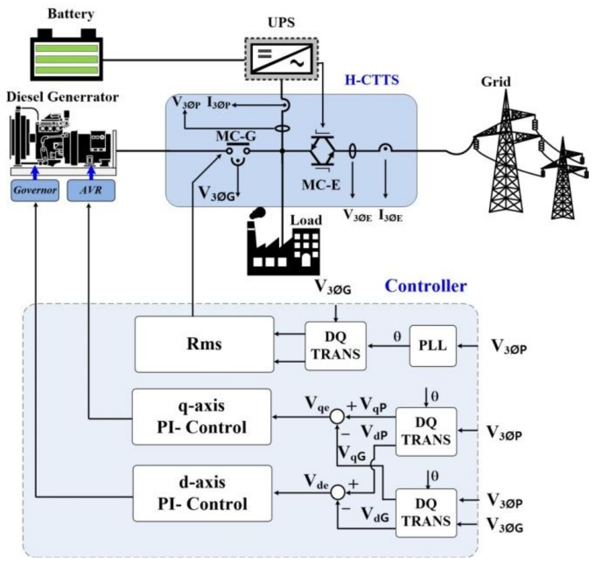


Figure 2:. The proposed uninterruptible CTTS system

Figure 2 shows a block diagram of the hybrid CTTS proposed in this paper. In the proposed system, bidirectional IGBTs were used as fast static switches to isolate the grid side instantaneously during unexpected power failure. Therefore, the UPS detects power failure and supplies power, and at the same time removes inrush current from the UPS to the Grid side by disconnecting the Grid side from the high-speed IGBT switch by the MC-E signal. This UPS system recovers power failure within 1/4 of the grid cycle. When the finite source inverter and generator that supply power to the load by the UPS are switched, the inrush current greatly affects the grid stability. Therefore, in order to prevent this, a hybrid CTTS control algorithm capable of linking the emergency generator with a fixed degree is required. In this paper, the virtual coordinate conversion value obtained by converting the generator voltage (V3ΦG) to the rotational coordinate system based on the phase angle information based on the UPS voltage (V3ΦP) is obtained for linking the emergency generator with high accuracy. And we control the governor and AVR of the generator as shown in Figure 2 to estimate the d-q voltage on the rotating coordinate system based on the phase angle information based on the UPS voltage (V3ΦP).That is, in the proposed virtual rotational coordinate system, the d-axis component becomes a frequency component and the q-axis component becomes a voltage component. Therefore, when the d-axis component on the virtual rotation coordinate system is controlled to be 0, the generator voltage frequency becomes equal to the grid voltage frequency. If the q-axis component of the virtual rotation coordinate system is controlled by the q-axis voltage of the system rotation coordinate system, the generator voltage and the grid voltage become equal. To detect the switching point, I have improved the degree of voltage detection using a method of detecting the difference in magnitude and phase difference between different power sources. In order to compensate the fluctuation of the generator frequency when the load of the stand-alone generator suddenly changes, an algorithm that detects the active power instantaneously and performs feedforward control using it is applied. In addition, in grid connections, an active power proportional integral controller and a reactive power proportional integral controller apply an algorithm that performs feedforward control to maintain stable dynamic characteristics while minimizing system phase margin. In the emergency generator system, the feedforward control by auto-tuning is used because the feedforward control depends on the generator age.

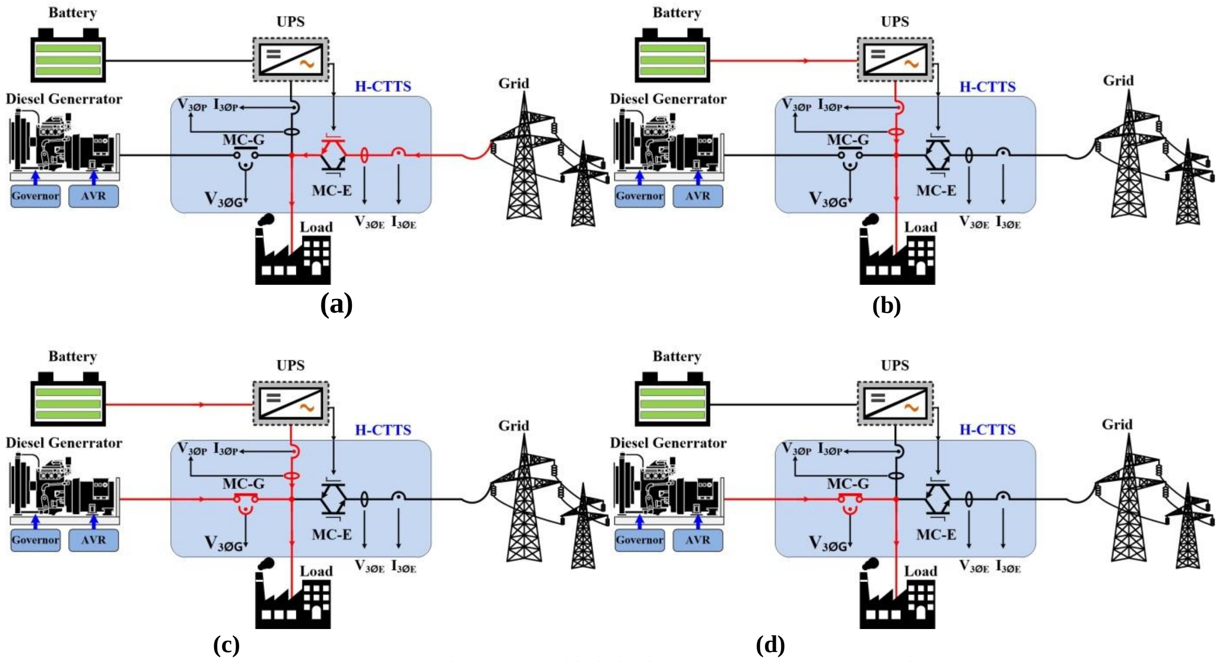
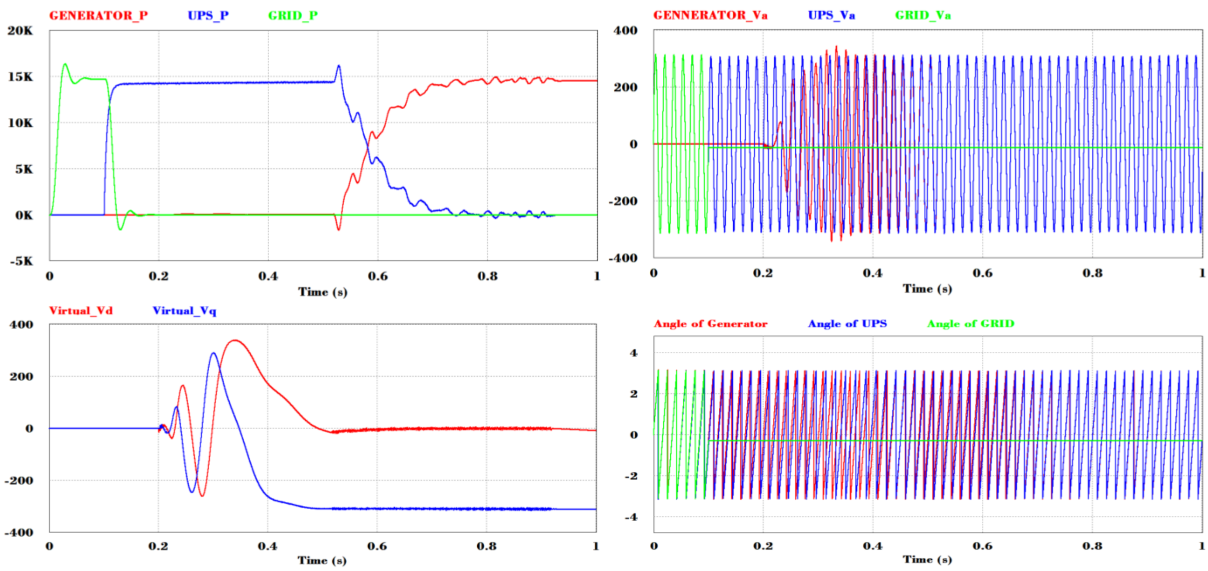


Figure 3:.Proposed Uninterruptible hybrid CTTS System Operating Modes

Figure 3 shows the operation mode of the proposed uninterruptible hybrid **CTTS** system. First, (a) mode is when the system power is in a normal state, and MC-E is ON, and the entire load power is transferred from the grid. Second, (b) mode is a power failure due to a grid fault. If a power outage occurs while measuring grid voltage and phase in real time, the UPS recognizes that a power outage has occurred and turns off MC-K and creates a three-phase power source that is responsible for the load power. Then, the diesel generator measures the UPS voltage and converts it into the virtual rotation coordinate system, which is the proposed method, and the generator controls the generator voltage and frequency according to the connection conditions. Third, when the connection condition is set in (c) mode, the proposed hybrid CTTS is switched and operates in the connected generator mode. Also controls active and reactive power of the UPS by controlling active power and reactive power. Fourth, in (d) mode, when the UPS's active power and reactive power reaches 0, the UPS operation is stopped. At the same time, the generator operates in the stand-alone generator control mode and takes charge of 100% of the load power.

Figure 4 shows the simulation results for analyzing the detection characteristics of the high-accuracy switching point by the generator rotation angle virtual rotation coordinates. In this simulation, the time of simulation is shortened by 10 times faster than the time constant of the actual generator system. As shown in the figure, a power failure occurs in 0.1 second and the UPS generates 3 phase power immediately. Also, the diesel generator starts at 0.2 second and the virtual d-axis voltage converted to virtual rotation coordinates is controlled to 0, and the q-axis voltage is controlled to 311 V, which is the maximum value of the UPS output, to match the generator voltage and frequency to the UPS.CTTS MC-G to diesel generator is ON and connected to UPS at approximately 0.5 seconds after satisfying stable conditions. It can be seen that the diesel generator side current of the CTTS at the moment of connection increases gradually starting from zero. At this time, active power and reactive power on the diesel generator side are controlled so that the active power and reactive power on the side of the UPS become zero, and the total amount of the load power is supplied from the generator side. It can be seen that the power controller is controlled while oscillating while the forward controller is not configured.

3. Simulation Result



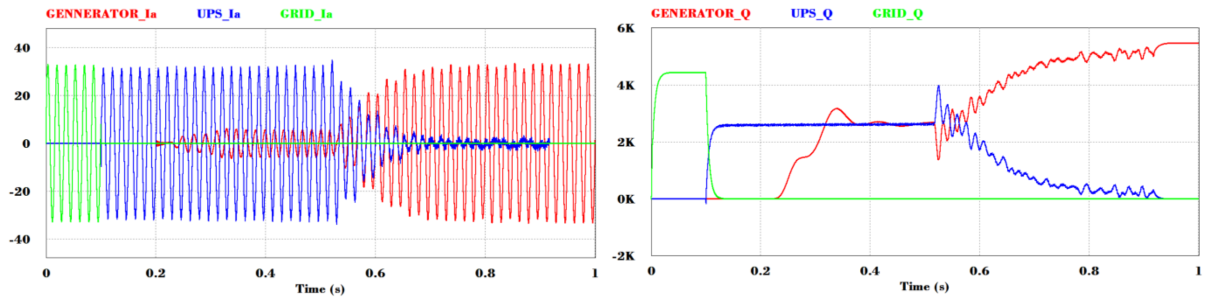


Figure 4:.Characteristics of fixed switching point detection by generator voltage virtual rotation coordinates

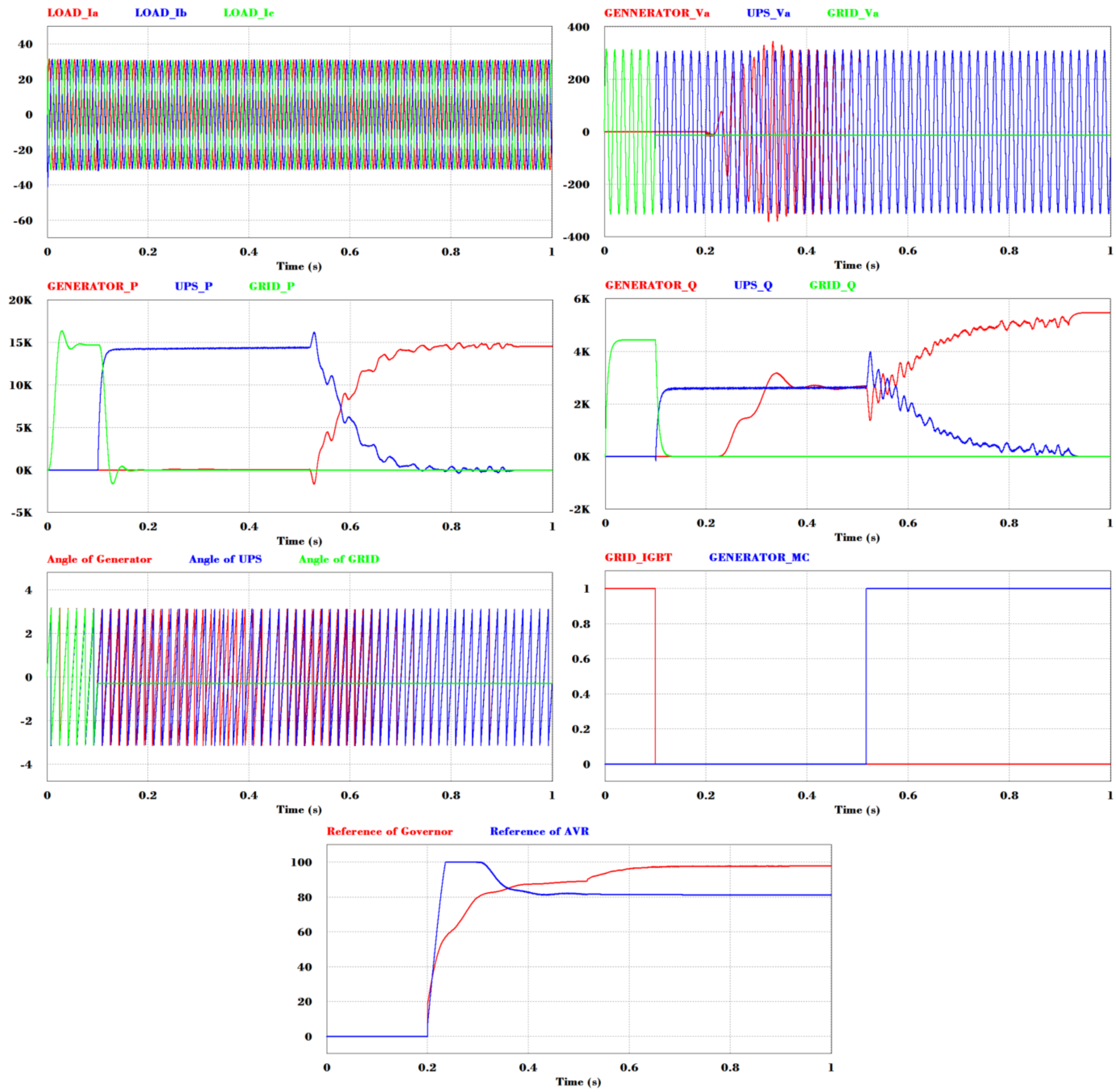


Figure 5:.Characteristics of CTTS controller capable of zero power switching

Figure 5 shows the simulation results for analyzing the characteristics of the CTTS controller capable of zero power switching. The condition is that the generator and the UPS are connected to the load at the same time for about 0.4 seconds until 0.9 seconds, and the independent generator system that supplies power to the load by the generator after 0.9 seconds. Analysis of the load side current shows that the load current fluctuates during power failure, but the UPS voltage is stable and the load current is supplied stably. Also, when the generator is connected to the UPS, it can be confirmed that current is being supplied.

4. Conclusion

In this paper, we propose a new CTTS structure suitable for a hybrid system combining a short - term UPS and an emergency generator, and it is possible to control the switching condition with high precision through the proposal of the generator voltage virtual rotation coordinate system based on the voltage phase angle. In addition, a variety of different power sources have been detected to detect size and phase error with high accuracy. This confirms that the inrush current can be reduced when the CTTS is charged. Especially, by controlling the active power and reactive power of the generator, it was possible to stabilize the arc and system by controlling the UPS output current to zero current when shutting off the CTTS.

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