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Hitachi SJ700D Variable Frequency Drives (VFDs)

Introduction

Hitachi's **SJ700D Series** of Variable Frequency Drives (VFDs) is a line of high-performance, general-purpose inverters designed for precise motor control and robust industrial use. Introduced as the successor to the SJ700B, the SJ700D drives incorporate advanced features such as enhanced sensorless vector control (for high torque at low speeds), an integrated PLC-like programming function, and built-in power conditioning components [1] [2]. The series spans a wide range of capacities, from fractional horsepower units in the low-voltage (200–240 V) class up to large high-voltage (380–480 V) models supporting **over 100 HP** (with some literature noting availability up to ~150 kW or ~200 HP) [3] [4]. This broad range allows the SJ700D to be deployed in diverse applications, from small machine tools to large industrial systems, with configurations for heavy-duty (constant torque) or normal-duty (variable torque) workloads. In short, the SJ700D drives deliver **powerful performance, flexibility, and ease of use** for a variety of motor control needs.

Key Features and Innovations

The Hitachi SJ700D VFDs distinguish themselves with several key features and technical innovations:

- **High-Torque Sensorless Vector Control:** The SJ700D employs an improved sensorless vector control algorithm with auto-tuning, enabling **very high torque at low speeds** without requiring an encoder. It can achieve **200% of rated torque at ~0.3 Hz** and even maintain around **150% torque at 0 Hz (zero speed)** under the right conditions [1] [5]. This 0 Hz domain control is ideal for heavy loads like hoists or extruders that demand high starting and holding torque. By comparison, many standard drives deliver only a fraction of that torque at low frequencies, so the SJ700D's capability is a significant advantage for applications such as cranes, lifts, and cranes that need strong torque from standstill [2] [5].

- **Dual Duty Ratings (Heavy & Normal Duty):** The SJ700D series supports both constant-torque (CT) heavy-duty and variable-torque (VT) normal-duty operation. Each drive is rated for **150% overload for 60 seconds** (CT) to handle heavy loads, with a higher short-term surge (up to 200% for a few seconds) for acceleration [6] [7]. For lighter variable-torque applications (fans, pumps, etc.), the same drive can be applied to a larger motor (one frame size up) since less overload is required [8]. This *one-frame-size-smaller* selection for VT loads means users can often choose a more compact drive for pumps and fans, while still having the robust torque capability available if needed. This flexibility simplifies selection and can reduce cost for variable torque use cases.

- **Integrated Braking Transistor and EMC Filter:** To simplify installation and save space, the SJ700D drives come with key hardware features built in. Notably, models up to **22 kW (30 HP)** include an internal dynamic braking transistor for connection of a braking resistor, allowing faster deceleration and stopping without an external braking unit [9] [10]. Additionally, an **EMC/RFI input filter** is

integrated (on models up to ~150 kW) to meet **EN 61800-3 (2nd environment)** electromagnetic compatibility standards [10]. The built-in filter attenuates electrical noise, helping the drive comply with CE requirements for conducted and radiated emissions. These integrated features reduce the need for external components, lowering total system cost and ensuring **"trip-less" operation** by absorbing regenerative energy and suppressing voltage spikes during decel [11]. (For very large models above 22 kW, external braking units or line filters may be used if needed.)

- **Easy Sequence (EzSQ) Programmability:** A standout feature of the SJ700D is its **built-in programming environment** called *Easy Sequence* (EzSQ), essentially a simple PLC-like logic controller inside the drive. Using a BASIC-like high-level language, users can program up to **512 steps** of logic to run on the drive's CPU [12]. This means the VFD can execute custom sequences and control external I/O without a separate PLC in some cases. **Real-world examples:** OEMs have used EzSQ to implement a "swift lift" function on cranes (automatically adjusting hoist speed based on load), pump "sleep" modes (stopping a pump when demand is low), load sharing between multiple motors, timed speed changes, etc. [13]. The drive monitors its inputs (e.g. sensors, switches) and can make decisions – for instance, alternately running two motors or coordinating a simple process – all internally. This integrated logic capability not only reduces the need for extra control hardware, but also speeds up responses (since the logic runs in the drive) and is easier to maintain via the drive's interface. **User-friendly software** (Hitachi's ProDriveNext PC tool) is available to write and download EzSQ programs, and the standard keypad can also be used to configure simpler sequences.

- **Position Control (Servo-Like Performance):** With the addition of an optional encoder feedback board, the SJ700D can perform **full closed-loop vector control** and even basic position control tasks [14] [15]. In other words, when outfitted with the encoder option and paired with an encoder-equipped motor, the drive can precisely control motor speed and position, offering servo-like functionality for positioning applications. This is particularly useful for indexing conveyors, lifts with floor leveling, or any application where stopping at a precise position is required. The SJ700D's position control mode, while not as advanced as a dedicated servo drive, can handle many positioning needs in packaging machines or material handling systems without the cost of a separate motion controller [16]. This versatility (open-loop vector for most cases, with upgrade to closed-loop if needed) makes the SJ700D suitable for a wider range of challenges.

- **Comprehensive Protection and Reliability Features:** Hitachi designed the SJ700D for long service life and high reliability in industrial environments. The drives use **long-life components** (such as capacitors and cooling fans) rated for about **10 years of continuous operation** under normal conditions [17] [18]. They also include an **"end-of-life" warning function** that alerts users when critical components are nearing wear-out, enabling proactive maintenance [17]. For day-to-day protection, the SJ700D has an extensive array of fault protections: over-current, over-voltage, under-voltage, motor overload (thermal modeling), external fault trip, ground fault detection, overheating, and many more are monitored continuously [19] [20]. There are even specific alarms for things like encoder loss, internal memory error, or too low speed at high load (to prevent stall) [21] [22]. This comprehensive protection suite helps prevent damage to the drive and motor, and the **trip avoidance functions** (such as automatic voltage regulation on the DC bus during deceleration and current suppression during overload) work to **minimize nuisance tripping** [23] [24]. In practical terms, the SJ700D tries to keep running through brief power dips or sudden load changes by modulating its output, thereby improving uptime.

- **User-Friendly Operation and Interface:** Despite its advanced capabilities, the SJ700D is designed to be user-friendly for operators and engineers. The **standard keypad** features a multi-digit display and can be set to show only user-selected parameters or basic modes for simplicity [25]. There are multiple display modes (basic, user, and compare mode) to help users navigate settings quickly. Parameters from a previous Hitachi drive (like the earlier SJ300 series) can even be uploaded and transferred to an SJ700D via the remote operator, thanks to backward compatibility of settings and terminal configurations [25]. Start-up is further simplified by an **improved auto-tuning** routine that identifies motor characteristics automatically [15]. For commissioning and programming, Hitachi's **ProDriveNext** software (PC-based) offers a graphical interface to edit parameters, monitor performance, and write EzSQ programs, making drive configuration and diagnostics more efficient. Maintenance is also eased by hardware design: for example, the cooling fan assembly is easily removable on larger units for cleaning or replacement [26], and modular construction allows quick access to control boards. All these considerations mean that integrating and using the SJ700D is relatively straightforward, even given its rich feature set.

Technical Specifications

The Hitachi SJ700D Series comes in two main voltage classes with numerous model options to cover different power ranges. Below is a summary of its technical specifications and capabilities:

- **Power & Voltage Ratings:** Models are available for **3-phase 200–240 V AC** input (designated by "L" in the model) from about **0.5 HP up to 75 HP** (0.4 to 55 kW), and for **3-phase 380–480 V AC** input ("H" models) from around **1 HP up to 200+ HP** (0.75 to ~150 kW) [3] [4]. (The largest models in some documentation extend to 400 kW (~500 HP) for high-voltage, though those may have been developed later or built to order [4].) All units are designed for 50/60 Hz mains and can tolerate input voltage fluctuations (typically +10%/−15% of nominal). Smaller kW ratings in the 200 V class can also accept single-phase input with appropriate derating, which is useful for cases where only single-phase supply is available – the drive will internally convert it to run a three-phase motor.

- **Output Range and Motor Control:** The inverter's output frequency range is **0.1 to 400 Hz** (with resolution up to 0.01 Hz) for broad speed control range [27] [28]. It supports multiple control modes:

- *V/Hz (Volts/Hz) control* – both constant torque V/Hz (for standard loads) and variable torque V/Hz (with a square-law reduction for fans/pumps) or even user-customizable V/Hz patterns.
- *Sensorless Vector Control* – for high dynamic performance and torque without feedback, as discussed in features.
- *Closed-Loop Vector Control* – when the optional encoder feedback module (e.g., Hitachi SJ-FB board) is installed, allowing precise speed/torque control and position control capability [14] [15].
- Notably, the SJ700D can even run **permanent magnet (PM) motors** in sensorless mode (in V/T mode), which adds flexibility for high-efficiency motor types (this is a feature indicated in Hitachi documentation for the series) [29].

The drive's speed regulation in vector mode is quite tight – holding within about **±0.5%** of set speed in open-loop vector [30], and even more precise with closed-loop (usually ±0.01% slip compensation). Torque control mode is available as well for applications requiring direct torque reference. Acceleration and deceleration times are programmable from 0.01 to 3600 seconds, with linear or S-curve (sigmoid) profiles

selectable to reduce mechanical stress [31]. This wide adjustability helps in tuning the ramp rates to suit different applications (e.g., slow ramp for a conveyor vs. quick ramp for a machine tool).

- **I/O and Interface:** The SJ700D is equipped with a robust set of input/output terminals for control and monitoring. Standard I/O includes **8 digital inputs** (configurable for NPN or PNP logic, and one can be assigned as a dedicated "Safe Stop" input to meet emergency stop safety requirements), **1 thermal sensor input** for motor overtemperature (PTC/NTC thermistor), **5 digital outputs** (open-collector type for status signals), and at least **1 programmable relay output** (form C contact) for alarm or run indications [32] [33]. On the analog side, there are typically **3 analog inputs** (two voltage inputs 0–10 V or ±10 V, and one current input 4–20 mA) and **2 analog outputs** (one 0–10 V and one 4–20 mA) for speed, torque or feedback signals [34] [35]. (Some documentation notes a third analog output in PWM form, but in practice the unit has two analog output channels available for use.) These I/O points are all user-programmable – the drive offers **68 possible functions assignable to inputs and 48 to outputs**, allowing customization of start/stop logic, preset speeds, fault triggers, indicator lights, etc. [36].

For communication, the SJ700D includes a built-in **RS-485 serial port** using Modbus RTU protocol, which allows linking the drive to HMIs, PLCs or supervisory systems for remote control and monitoring [37]. The protocol supports programming and reading drive parameters as well as controlling operation. In addition, Hitachi provides optional **fieldbus interface modules** for popular industrial networks – including **Profibus-DP**, **DeviceNet**, and **CANopen** – which can be installed to integrate the VFD into a plant-wide network [38] [39]. These communication options enable the SJ700D to fit into modern automated systems seamlessly, whether it's a stand-alone drive with simple Modbus or part of a complex PLC-controlled line via a fieldbus.

- **Power Conditioning & Efficiency:** To ensure smooth operation on power systems, the SJ700D drives come with or recommend power conditioning components. As mentioned, an **EMI/RFI filter is built-in** for electromagnetic compliance and noise reduction [10]. For larger horsepower models, **DC link reactors** (DC chokes) are either built-in or supplied loose (depending on model size) to help reduce input current harmonics and improve the power factor. The drives are also designed with an extended DC bus capacity and **automatic voltage regulation (AVR)** on deceleration: if the DC bus voltage rises due to regenerative energy (e.g., a fast decel of a high-inertia load), the SJ700D will temporarily extend the decel time or engage dynamic braking to prevent an over-voltage trip [23] [24]. This "trip avoidance" function keeps the drive running through transient conditions that would trip lesser VFDs. The efficiency of the drive itself is high (inverter efficiency typically around 95–98%), and with features like energy-saving modes and optimized PWM control, it minimizes losses. The switching frequency is adjustable (up to ~15 kHz for smaller units, lower for very large units) to allow a balance between acoustics, efficiency, and motor heating [40] [41].

- **Standards and Certifications:** The SJ700D series is globally certified for safety and performance. It carries **CE marking**, UL and cUL certifications, and meets the applicable IEC/EN standards for drives. Notably, it conforms to **EN 954-1** (Category 3) for safe stop functionality [1], which has since been succeeded by ISO 13849-1, indicating that the drive can be integrated into safety circuits (with a "Safe-Off" input that disables the drive's output in a predictable manner). The **IP20 enclosure** rating is standard for most models (meaning finger-safe but not dust-tight or waterproof), suitable for mounting inside control panels [42]. Higher power models may be IP00 (open chassis) and thus require installation in an electrical cabinet. The environmental specifications allow operation in ambient temperatures typically **-10 to 40°C** (up to 50°C with derating or additional cooling) and in up

to 90% non-condensing humidity [43]. These drives are robustly built to handle industrial environments, but like all VFDs, they should be protected from corrosive gases or excessive dust.

Applications and Use Cases

As a versatile and high-performance drive, the Hitachi SJ700D finds use across many industries and applications. Its feature set lends itself to both heavy-duty machinery and energy-saving motor control scenarios:

- **Heavy Industry and High-Torque Applications:** The SJ700D's ability to deliver **instantaneous high torque** makes it ideal for heavy industrial applications. **Crane and hoist systems** benefit from the 0 Hz domain control – for example, a crane using SJ700D drives can lift heavy loads smoothly from a standstill, with 150–200% torque available to prevent stall or rollback [7] [5]. Similarly, **extruders and mixers** in plastics or food processing, which often start under load, can rely on the drive's low-speed torque to begin turning dense material without external aid. In one use case, a large **vertical lift** was retrofitted with SJ700D drives to replace an older DC drive system; the result was improved low-speed holding torque (important for safety when holding loads) and a reduction in mechanical shocks due to the SJ700D's smooth ramping and torque control. The built-in braking transistor also aids these applications by dissipating energy during quick stops – e.g. an emergency stop of a hoist – thus **reducing stopping distance and time** while keeping the drive stable.

- **Pumps, Fans, and Energy Savings:** For variable torque applications like **centrifugal pumps, fans, and blowers**, the SJ700D offers not only suitable VT ratings but also energy optimization features. By replacing throttle valves or dampers with speed control, significant energy savings can be achieved. **Case studies have shown** that using VFDs in place of mechanical flow control can cut energy usage by **40–50%** in many pumping/fan systems [44]. For instance, a water treatment plant that installed VFDs (including models comparable to the SJ700D in the 50 HP range) on its pumps observed a ~45% reduction in energy consumption at low demand, as the drives could slow the pumps instead of wasting energy across a throttle valve [44]. The SJ700D's sleep function (programmable via EzSQ) is particularly useful in such scenarios – if flow demand drops to zero, the drive can automatically stop the pump and restart it when needed, avoiding continuous idling. Moreover, the soft-start capability reduces water hammer in pipelines and extends the lifespan of both motor and mechanical components. In HVAC systems, the SJ700D's integrated EMC filter helps meet strict building electrical noise standards, and its network communication options allow integration with building management systems for remote monitoring and control.

- **Manufacturing and Machine Automation:** The SJ700D is often found in **packaging machines, material handling systems, and general factory automation**. Its combination of high performance and programmability means a single drive can handle complex tasks. For example, in a **conveyor system**, an SJ700D can be programmed via EzSQ to perform an indexing motion: move a conveyor a set distance, stop for loading/unloading, then resume – all coordinated by the drive's internal logic and an encoder input for position feedback. This eliminates the need for a separate motion controller for many indexing tasks. In another example, a **bottling line** might use SJ700D drives to control the speed profiles of different sections (filler, capper, labeler) and use the built-in networking to synchronize speeds or report faults to a central PLC. The **multi-motor coordination** capability is enhanced by the drive's fast internal processing and networking – multiple SJ700Ds can share load information or be master-slave via communications. Additionally, **Safe Stop** integration

means the drives can be tied into E-stop circuits reliably: when an emergency stop is pressed, the SJ700D's safe torque off function will disable its output (category 0 stop) without damaging the drive, allowing machines to meet safety regulations more easily.

- **Comparison to Industry Peers:** The advanced features of the SJ700D reflect industry-wide trends in VFD design. Comparable drives from other manufacturers offer similar capabilities – for instance, ABB's ACS880 series implements high-performance vector control and even direct torque control (DTC) for precise torque response [45], and Yaskawa's GA800 family likewise provides sensorless control even for permanent magnet motors and includes onboard EMC filtering and network options as standard [46]. The SJ700D is very much in line with these high-end drives, providing *future-proofing* for users. Its EzSQ programming feature is one area that gives it an edge in certain scenarios by embedding PLC functions into the drive. The bottom line is that the SJ700D series brought Hitachi into the **top tier of general-purpose VFDs** at the time of its release, combining the reliability that brands like Yaskawa are known for with the innovative control features and flexibility demanded in modern automation.

Reliability and Maintenance

Long-term reliability is a critical factor for any industrial drive, and Hitachi put emphasis on design for longevity in the SJ700D series. Components such as electrolytic capacitors, cooling fans, and relays are specified for extended life. The drive includes an **elapsed time monitor and maintenance timers** to track how long critical components have been in operation [17] [47]. For example, it can estimate the remaining lifetime of the DC bus capacitors and provide an alarm when approaching end-of-life, allowing maintenance to be scheduled proactively. Users have appreciated that this reduces unplanned downtime – instead of a capacitor failure taking a line down, maintenance staff get a heads-up to replace parts during a planned stop.

From a service standpoint, the **modular construction** of the SJ700D simplifies repairs. The control PCB can be withdrawn for service or replacement without disturbing power wiring, and option cards (like network interfaces or feedback boards) plug in easily. The cooling **fan assembly is typically plug-and-play**, so a fan can be swapped in minutes, which is important since fans are one of the few moving parts and thus prone to wear [26] [48]. The drive's extensive self-diagnostic features also aid in troubleshooting – detailed fault codes and logs can be retrieved via the keypad or software, pinpointing issues from over-voltage trips to motor overloads or internal errors. Hitachi's documentation provides clear guidance on each fault, so users can quickly identify whether a trip was caused by, say, an input power dip or an internal fault, and take the appropriate action.

All SJ700D units are conformal coated on their circuit boards, which helps protect against dust and humidity, improving reliability in less-than-ideal enclosures. However, regular maintenance like keeping cooling vents clean and ensuring tight electrical connections will greatly extend the drive's life. When properly installed and maintained, the SJ700D drives have demonstrated **excellent mean time between failure (MTBF)** in the field – users often report many years of continuous operation without issues, comparable to the reliability reputations of industry leaders. This level of trust is crucial in 24/7 operations such as manufacturing plants or municipal utilities (water/wastewater pumping) where VFD failures can halt critical processes.

Conclusion

The **Hitachi SJ700D** VFD series represents a comprehensive solution for motor control, blending high-end performance with practical features that solve real-world problems. From its powerful low-speed torque and flexible dual-duty ratings to its built-in PLC functionality and network connectivity, the SJ700D exemplifies a *balanced design* – equally focused on delivering torque and speed control as it is on simplifying the user's experience in programming, integration, and maintenance. It can drive standard induction motors with precision, and even handle advanced tasks like position control or synchronous motor operation when required. Moreover, by including components like EMC filters and brake choppers internally, it reduces the burden on system designers to add extra hardware, making for cleaner and more cost-effective installations [10].

Although the SJ700D is a legacy series (with Hitachi's newer models like the SJ-P1 taking the baton in recent years), it remains a testament to robust engineering. Many units are still in service worldwide, providing energy savings, improved process control, and reliable operation in countless applications. Whether it's improving the efficiency of a pump system by matching speed to demand, or precisely controlling a crane carrying tons of load, the Hitachi SJ700D has proven capable. For facilities looking to upgrade older drives or engineers designing a new system, the SJ700D series offered a compelling mix of **performance, flexibility, and durability**, which is why it continues to be referenced as a benchmark in the evolution of variable frequency drives.

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