Rockwell Automation Drive System for TBM

Allen-Bradley · Rockwell Software

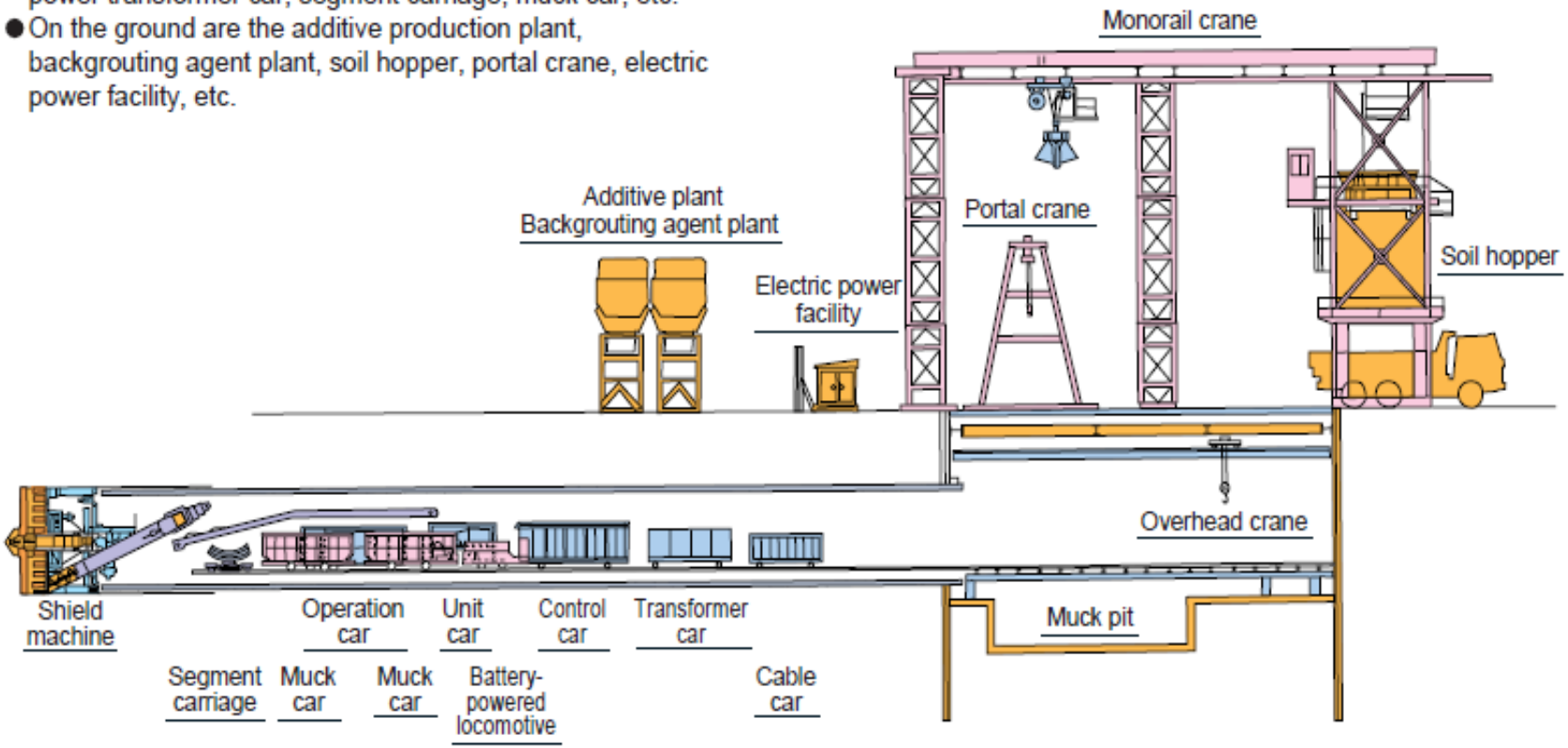
Rockwell Automation

Content

TBM Basic Introduction

System explanation

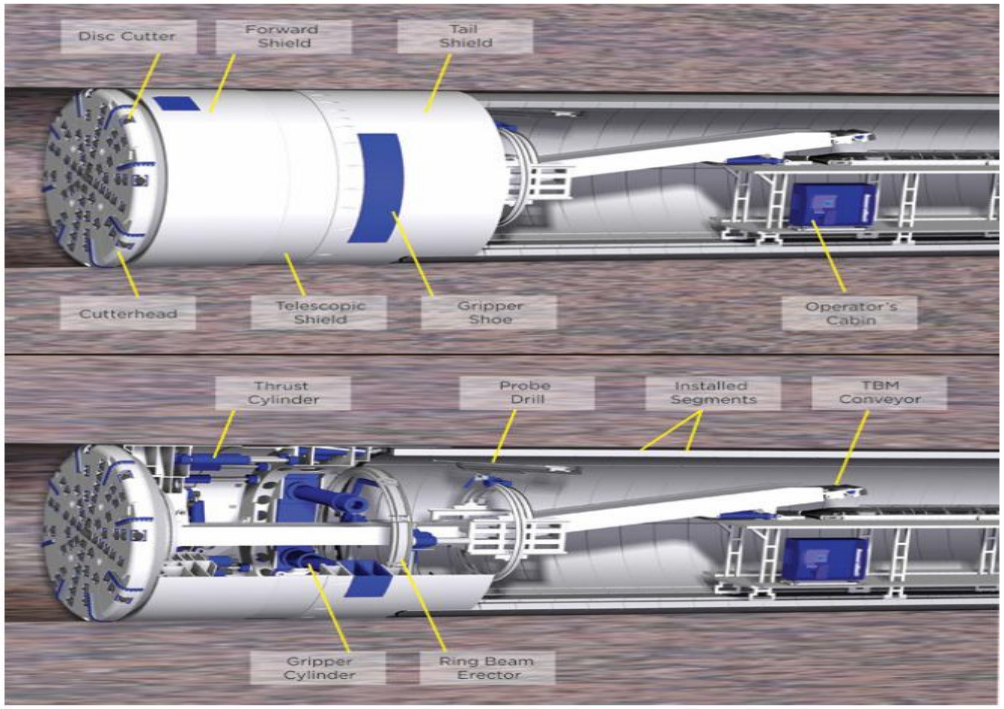
- The shied system comprises the shield, additive injection device, additive production plant, and other facilities.
- In the tunnel are the shield power unit car, power transformer car, segment carriage, muck car, etc.
- On the ground are the additive production plant, backgrouting agent plant, soil hopper, portal crane, electric power facility, etc.



TBM Basic Introduction

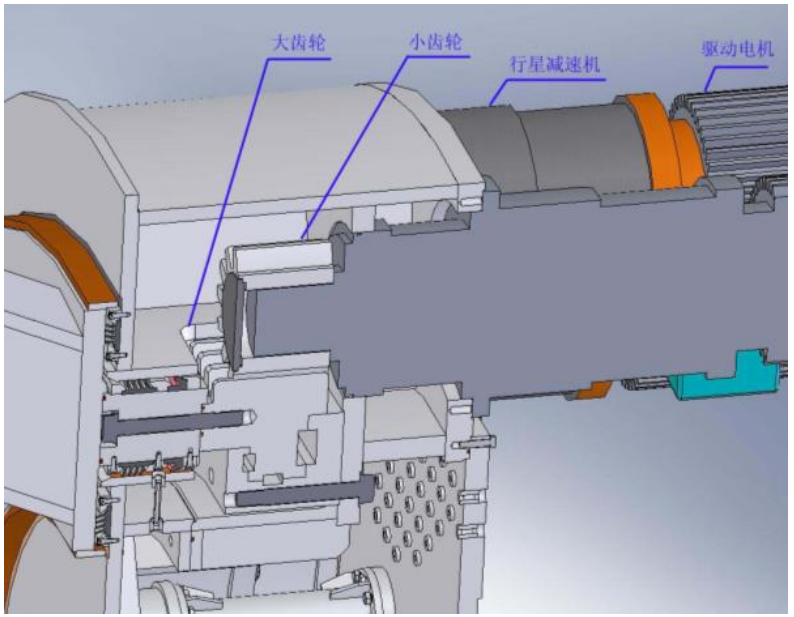
盾构机，全名叫盾构隧道掘进机，是一种隧道掘进的专用工程机械；盾构机的基本工作原理就是一个圆柱体的钢组件沿隧洞轴线边向前推进边对土壤进行挖掘。该圆柱体组件的壳体即护盾，它对挖掘出的还未衬砌的隧洞段起着临时文撑的作用，承受周围土层的压力，有时还承受地下水压以及将地下水挡在外面。挖掘、排土、衬砌等作业在护盾的掩护下进行。

盾构一个重要部件即切削刀盘，切削刀盘上带有固定刀具，整体装于盾构柱面，对前方的掘进面旋转，实现土层切削。

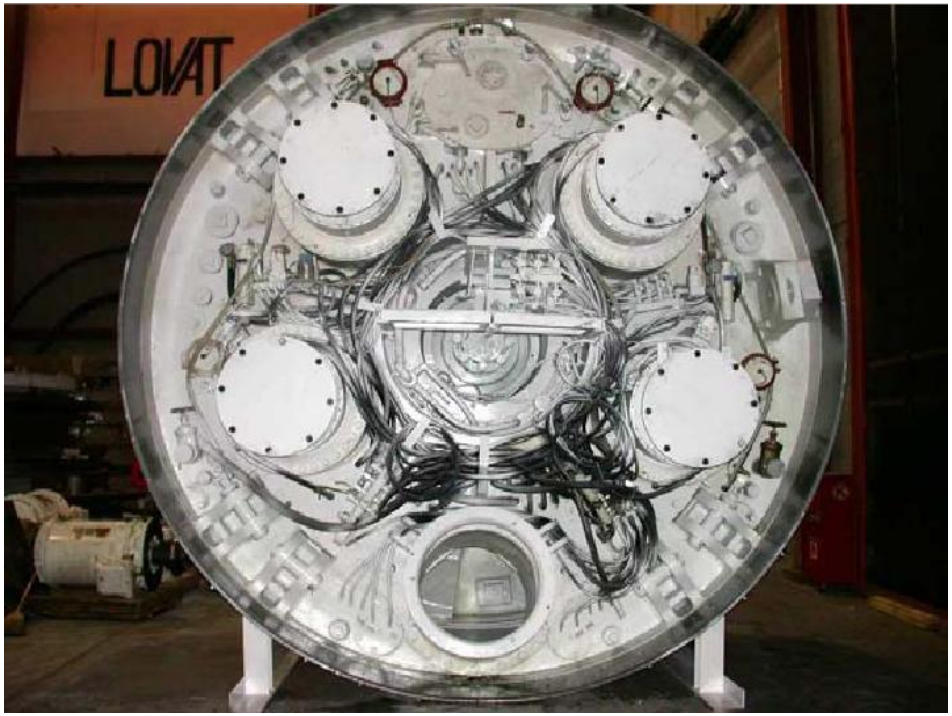


TBM Basic Introduction

- 共圆周布置8~10台电机，一般采用55KW或75KW的4P或6P三相电动机。
- 电机被驱动后，经过行减速机一级减速，再经过行星齿轮啮合到大齿轮箱，形成二级减速。机构被大齿轮机械硬连接。
- 示例参数要求：
- 最终旋转速度：0~3rpm，典型值0.2~2rpm
- 一极减速比例：电机选定配备的减速机定，减速比i为174.9
- 二极减速比例：减速比i为114/16
- 总体的扭矩要求：　　约 5700 KN·m
- 一般需要脱困扭矩：　大于 7000 KN·m



Rockwell Application in LOVAT



Main Drive Design

- Variable Frequency Electric Drive
- 600 kW Installed Power
- 540 kW Available at the Cuttinghead
- 250 t•m of torque at 0.0 to 1.9 rpm
- Maximum Speed of 4.3 rpm
- Peak Starting Torque of 314 t•m
- External Ring Gear on Main Drive Bearing

Variable Frequency Drive Efficiency

Ring Gear to Pinion Interface	= 98.5%
Planetary Gearbox	= 96.4%
VFD and Electric Motor	= 95.0%
Overall VFD System	**= 90.2%**

液压方式与电动方式效率比较

-更高的效率

更方便的安装维护

更低的成本

更清洁安静

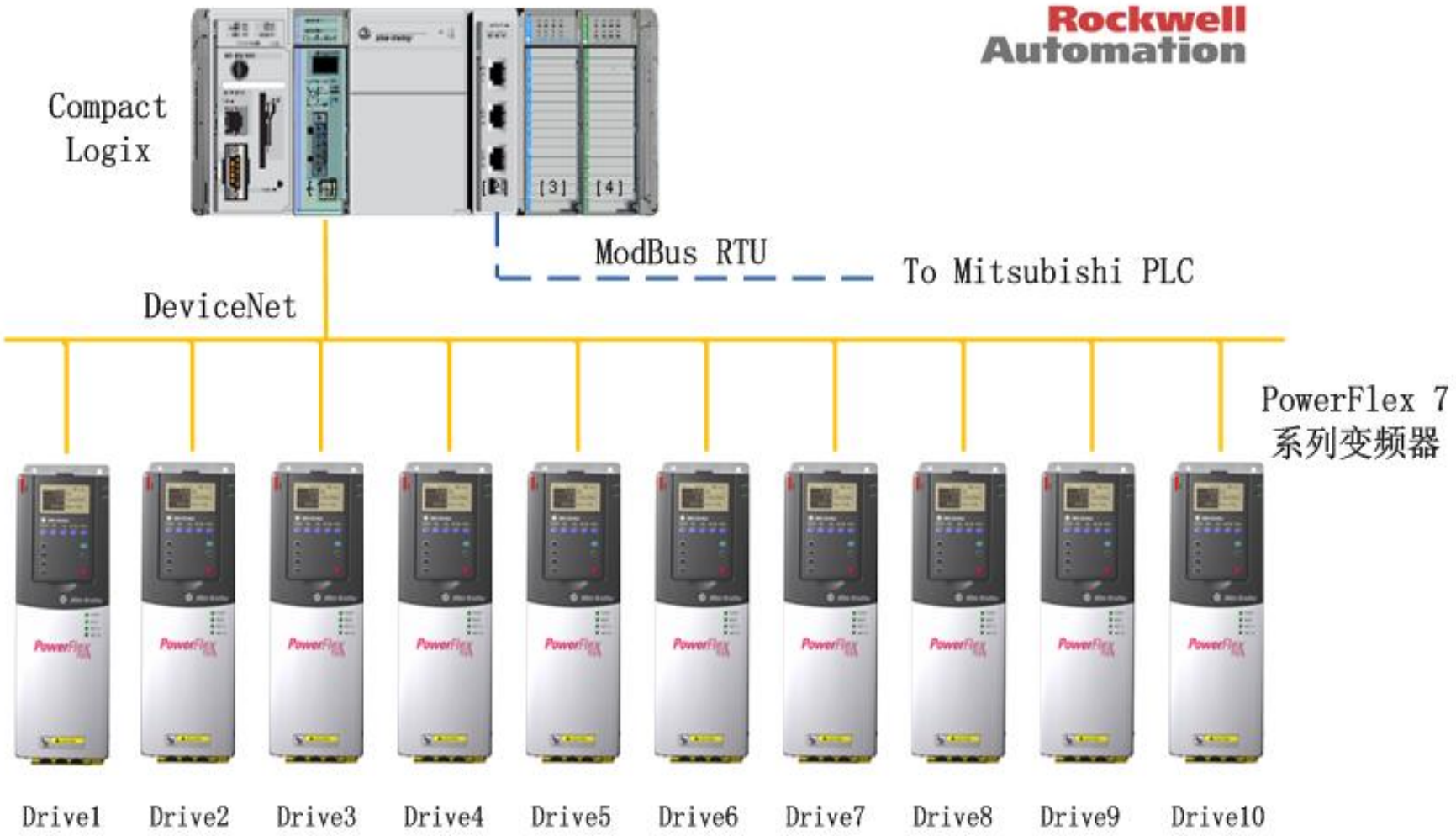
热能损耗更低

Hydraulic Drive Efficiency

Ring Gear to Pinion Interface	= 98.5%
Planetary Gearbox	= 96.4%
Hydraulic Motor - Mechanical	= 93.0%
Hydraulic Motor - Volumetric	= 98.0%
Hydraulic Pump - Mechanical	= 90.0%
Hydraulic Pump - Volumetric	= 97.0%
Electric Motor	= 97.0%
Overall Hydraulic System	**= 73.2%**

Content

System layout



VFD System Control

- 分控PLC接收主控PLC的命令，通过通讯方式同时起/停10台变频器,并发出档位速度命令.
- 主变频器接受速度指令，采用速度控制方式运行，同时将力矩给定通过通讯方式传递给从变频器.
- 从变频器接受速度指令作为速度限幅值，同时接受主变频器的力矩值，采用力矩方式运行，实现力矩跟随，保证各个马达出力相等.
- 当主变频器故障时，可通过PLC自动将1台从变频器转变为主变频器；
- 为保护机械设备，可在特殊情况下改变变频器力矩限幅值.
- 在紧急情况下，可忽略某些变频器故障状态，保证设备不停机；
- 分控PLC采集变频器数据，并通过通讯方式传递给主控PLC；

Content

VFD Design Consideration

- 变频器的尺寸和安装空间
- 变频器的防护等级
- 变频调速与负载分配
- 变频器的通讯
- 对机械传动机构的保护
- 温度扭矩等参数监控
- 安全性（安全停车）

PowerFlex Drives Products

PowerFlex® 700

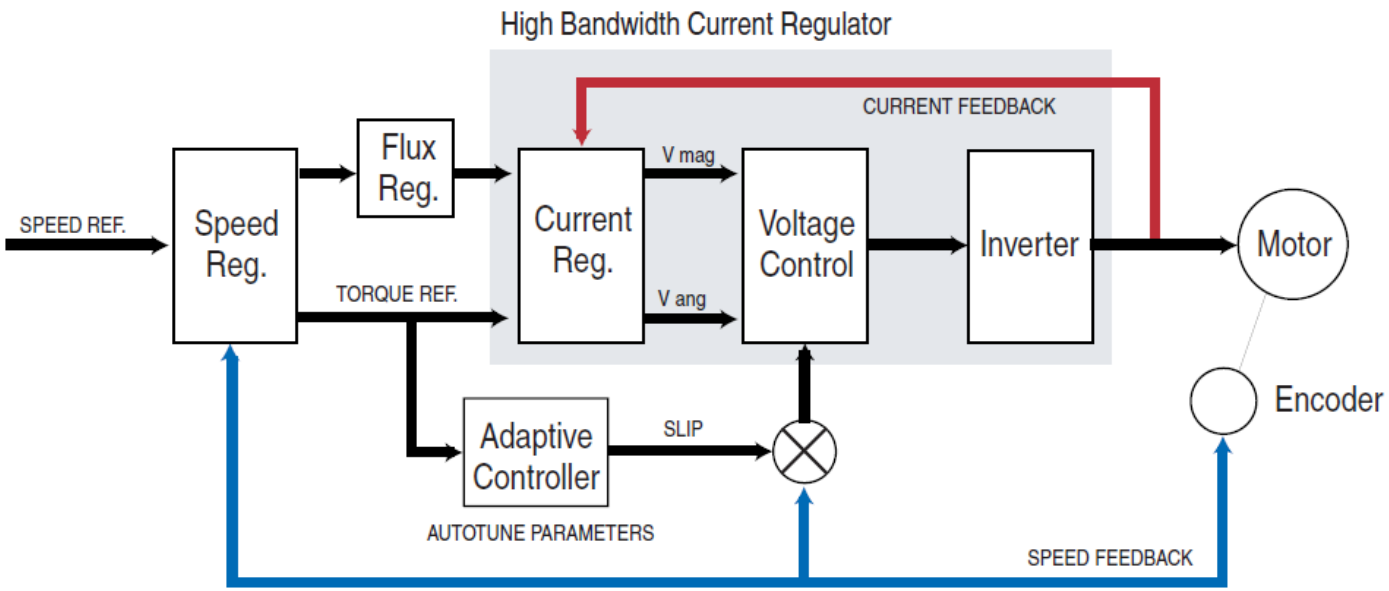
Optimised Flexibility

- General purpose drive to 132 kW
- Sensorless and flux vector (SVC, FVC)
- TorqProve™ and Positioning
- Compact with in-built braking
- Unique packaging – control cartridge
- Additional I/O and encoder interfaces

Motor Control

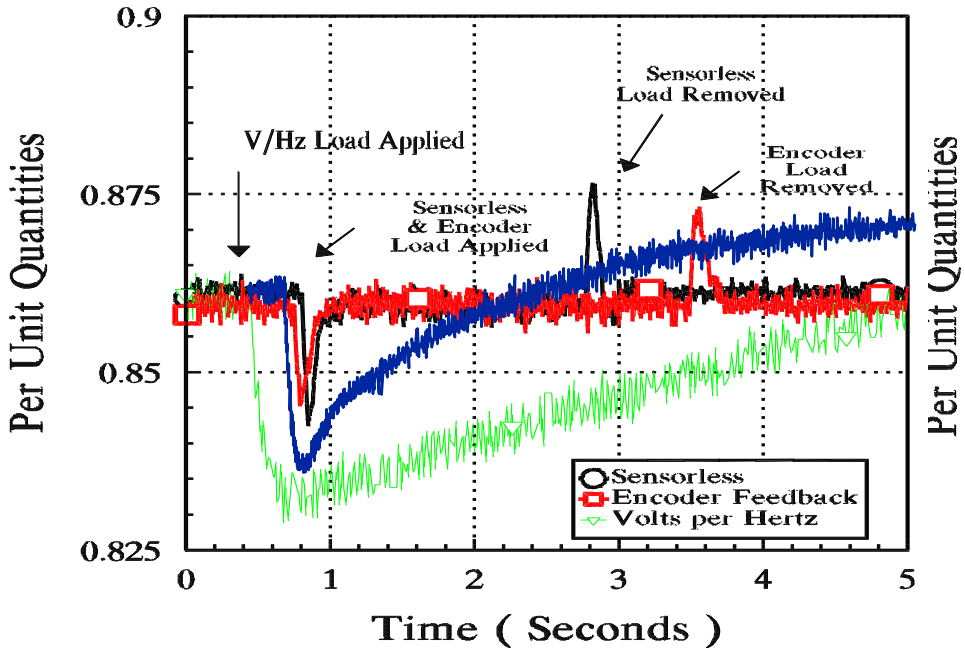
Field Oriented Control

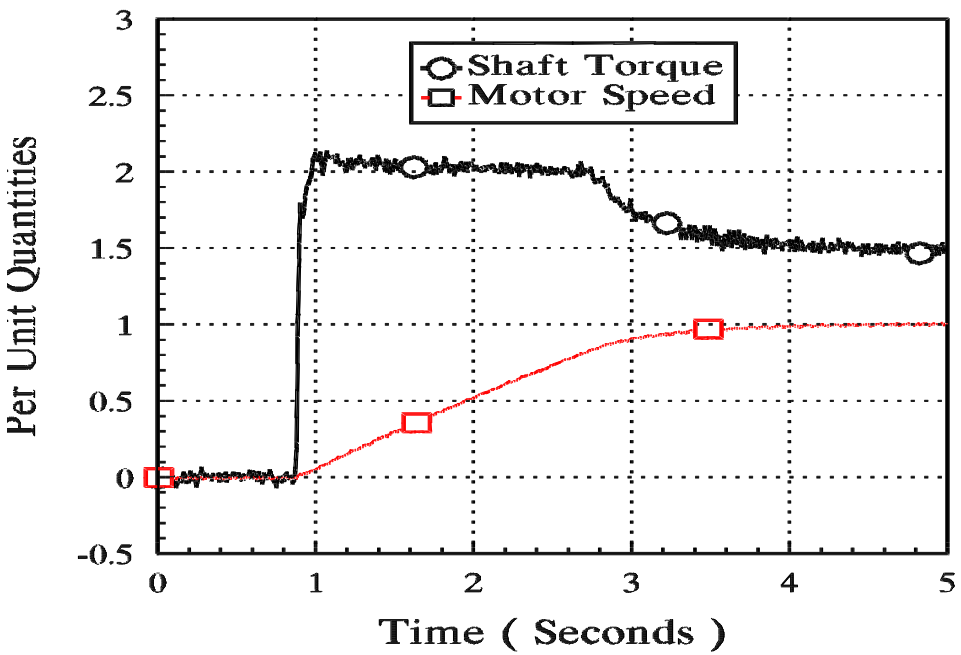
- In flux vector mode, the flux and torque producing currents are independently controlled and speed is indirectly controlled by a torque reference. Alternatively,the drive can control torque instead of speed in flux vector mode. In either case, this mode can be operated either with or without feedback and will provide the fastest response to load changes.



VFD Control Characteristic

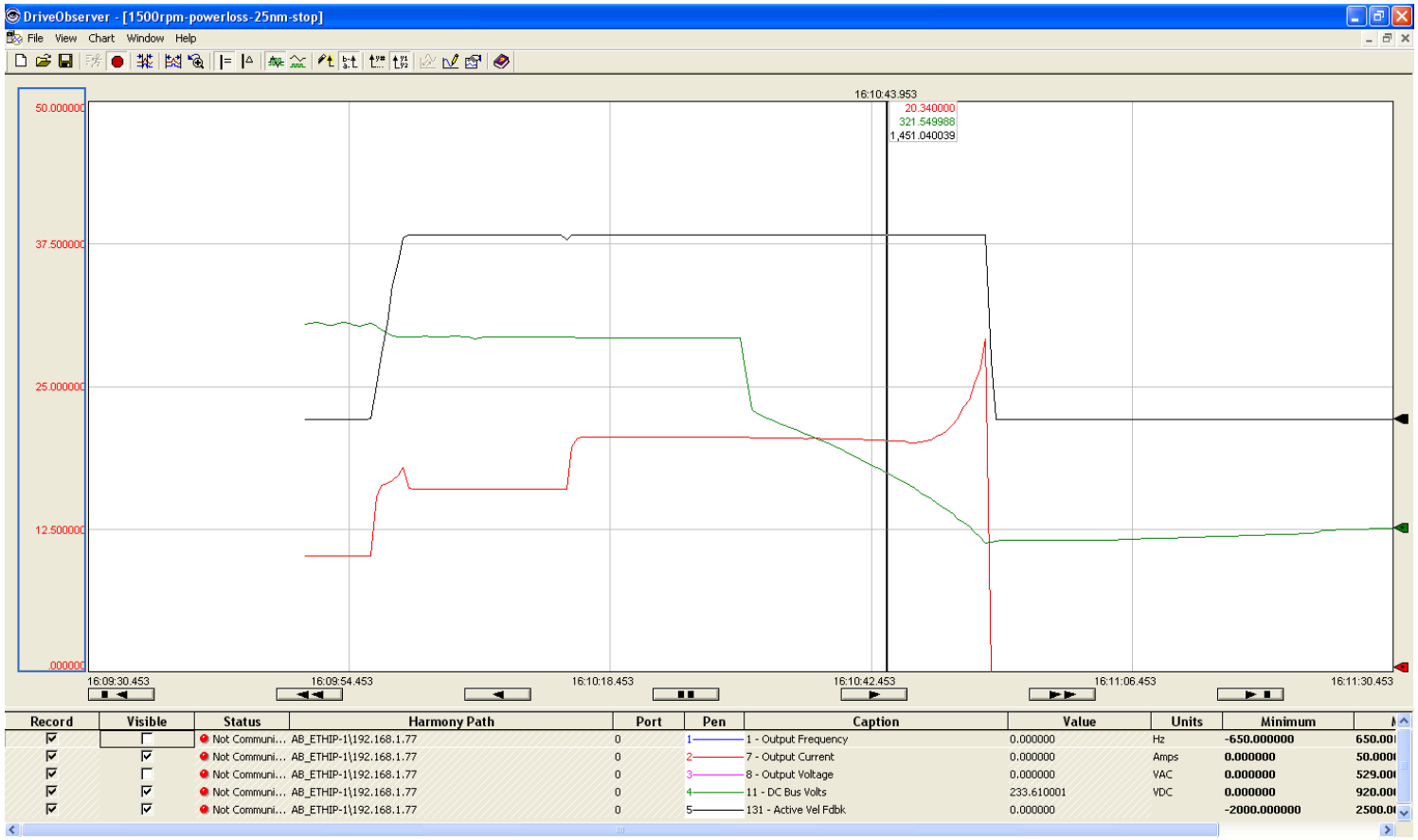
- **Perfect Speed feature**
- **抗扰动能力(better performance with encoder)**





VFD Control Characteristic

- DC Bus voltage dip 305VDC, constant power output;



VFD Control Characteristic

Space Saving Hardware Features

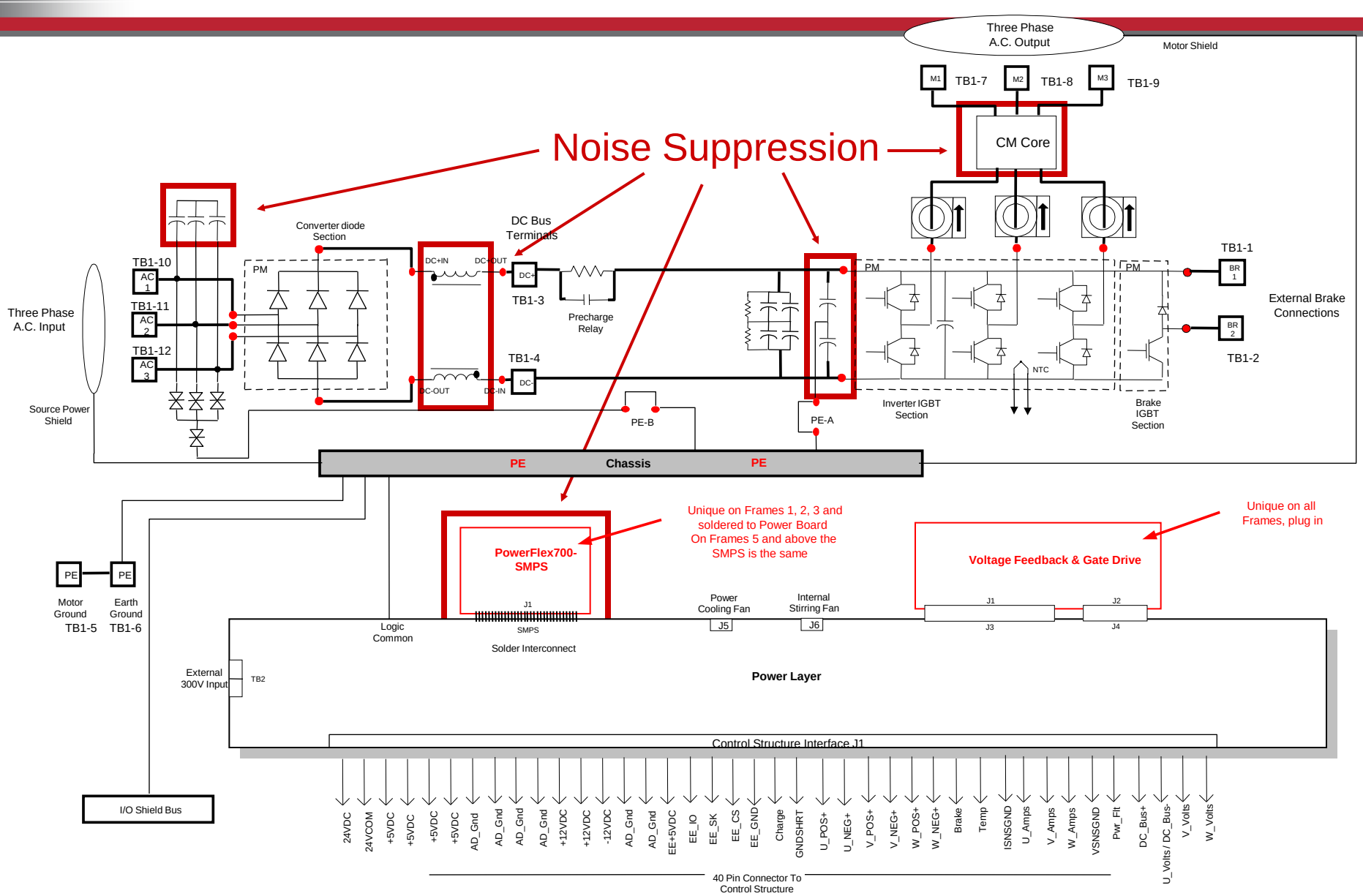
- **Integral EMC Filtering** plus built-in DC bus choke common mode cores and common mode capacitors provides a compact, all-in-one package solution for meeting EMC requirements, including CE in Europe.

- **Internal Communications** allow the user to integrate the drive into the manufacturing process. Status indicators for all internal communication options are visible on the cover for easy setup and monitoring of drive communications. Users can easily manage information from shop floor to top floor and seamlessly integrate their complete system as they control, configure and collect data.

- **Integral Dynamic Brake Transistor** delivers a cost effective means of switching regenerative energy without costly external chopper circuits. These internal transistors are available in all power ratings.

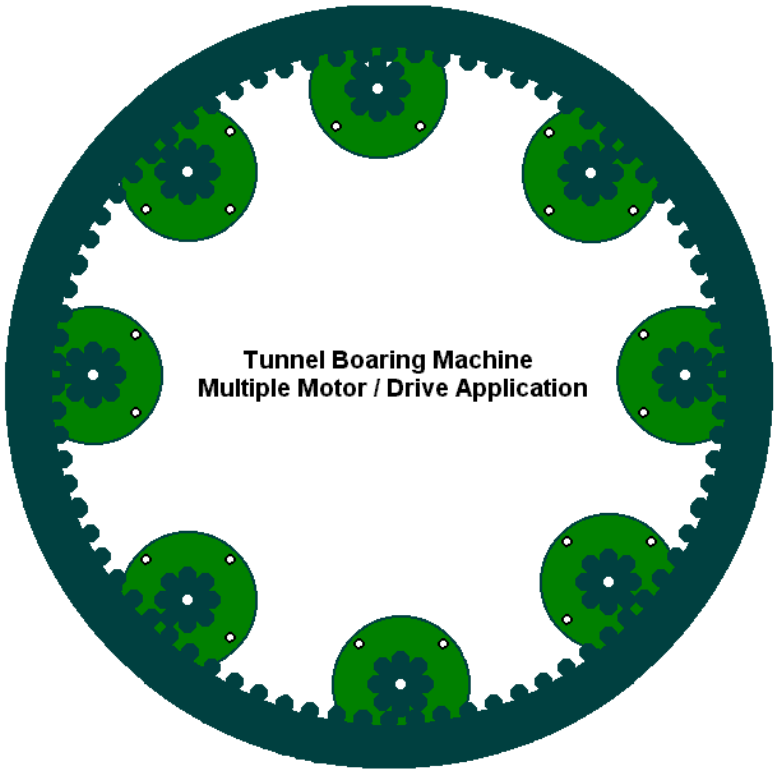
- AC 3% Line Reactor，current 100A，type：1321-3R100-B

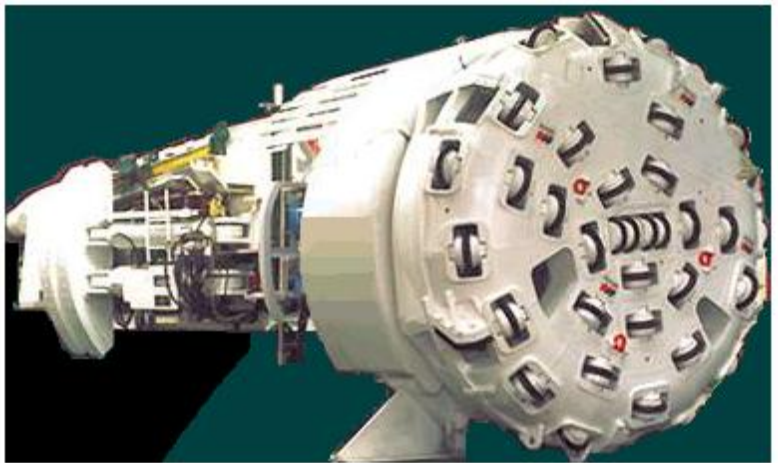
VFD Control Characteristic



Content

Load Sharing Control





1 Drive vs 1 Motor with Load Sharing

- Precise speed & Torque control.
- Field Oriented Control.
- Autotune to get precise motor data.
- Better protection of motors
- Higher system Safety than Common Bus system

LOAD SHARING
with
Drives and Motors

Load Sharing

- **What IS Load sharing?**
- **In the world of DRIVES Load Sharing:**

  - Involves multiple drives/motors powering the same process.

  - Is having each drive contribute a fair share of torque to do work proportional to its own capacity.

Load Sharing

- **What Load sharing IS NOT!**
- **In the world of DRIVES Load Sharing:**
- Is NOT multiple motors controlled by one drive powering the same process (Although this is a crude uncontrolled form of load sharing).
- Is NOT having each drive/motor combination operate entirely independent of each other.

A second form of Load Sharing requiring:

- Precise master slave load sharing.
- Precise speed regulation.
- To operate over a wide speed range.
- Multiple drives to act as ONE larger drive.

Using
DROOP FOLLOWER,

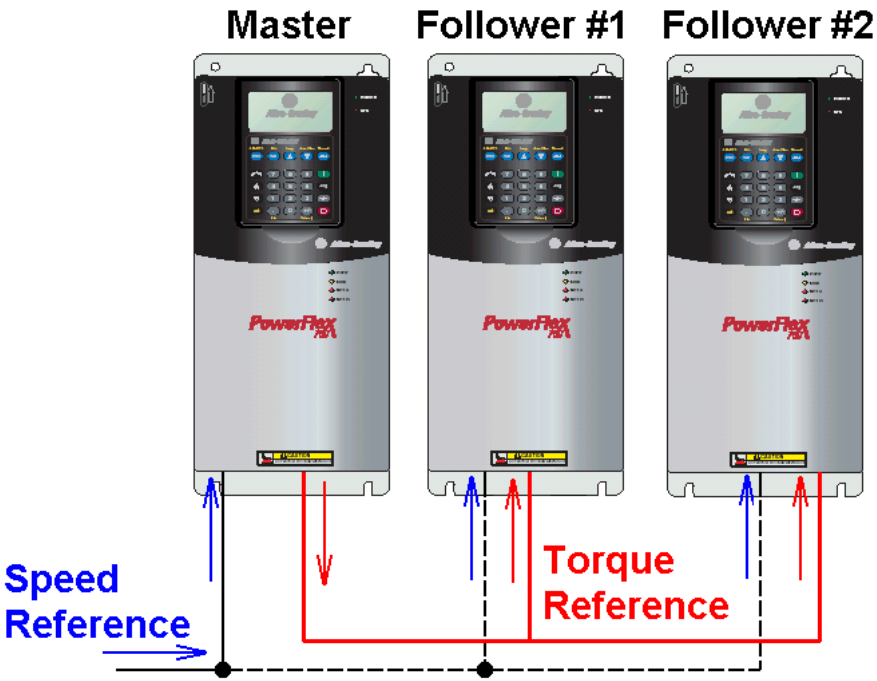
TORQUE FOLLOWER
(master / slave)

and

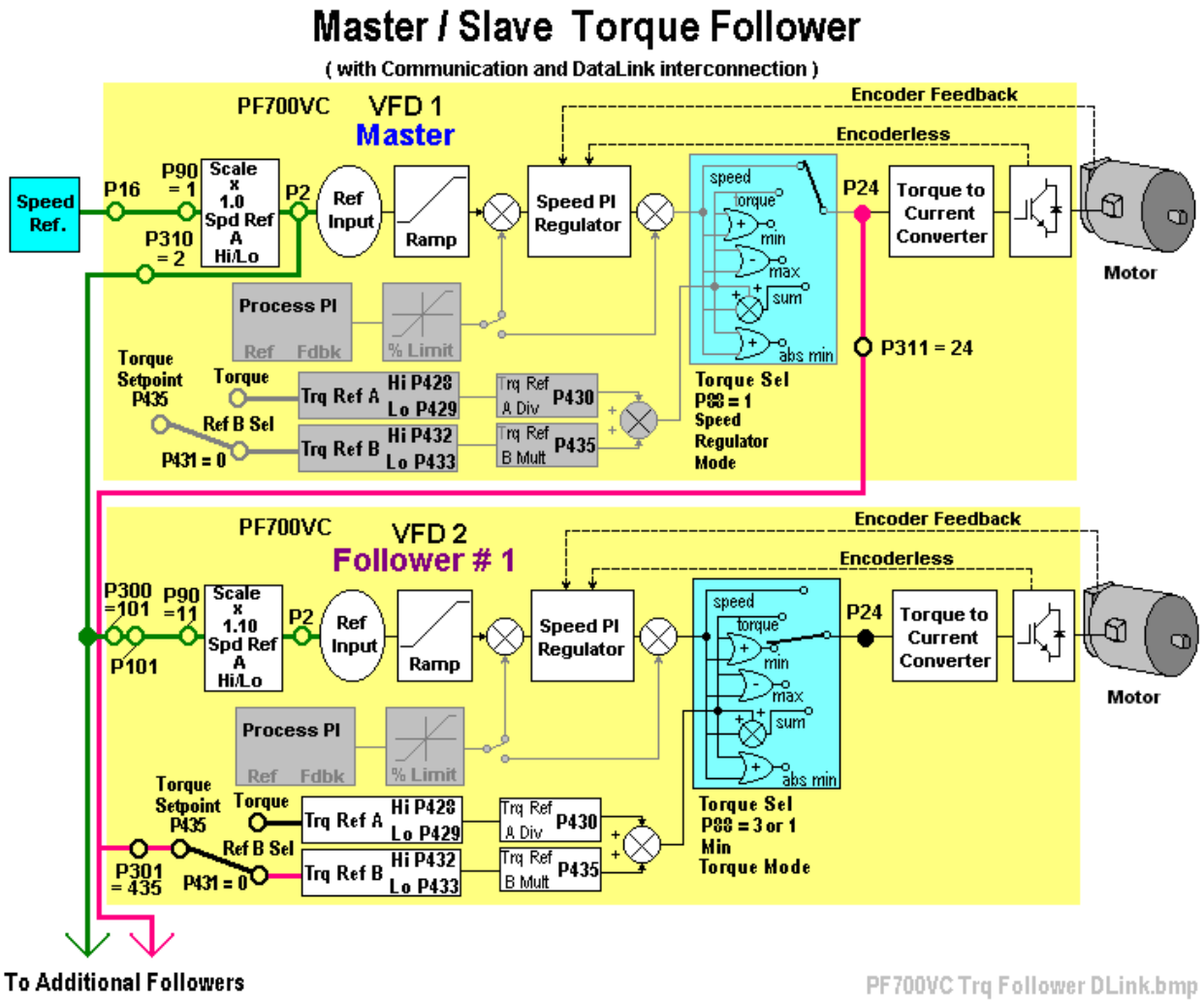
SPEED TRIM FOLLOWER

Torque Follower

- 主变频器采用速度控制模式，速度调节器输出值不仅作为本机的力矩调节器设定值，同时通过网络传递给从变频器，从变频器采用转矩控制模式，本机力矩反馈值与主机数据进行比较调节，保证本机的力矩调节器设定值与主机一致，使从机与主机的力矩输出一致；
- 同时从机与主机共用一个速度环，因而保证从机与主机速度一致，并在负载突然减小时，通过速度环输出限制电机转速的超速发生；

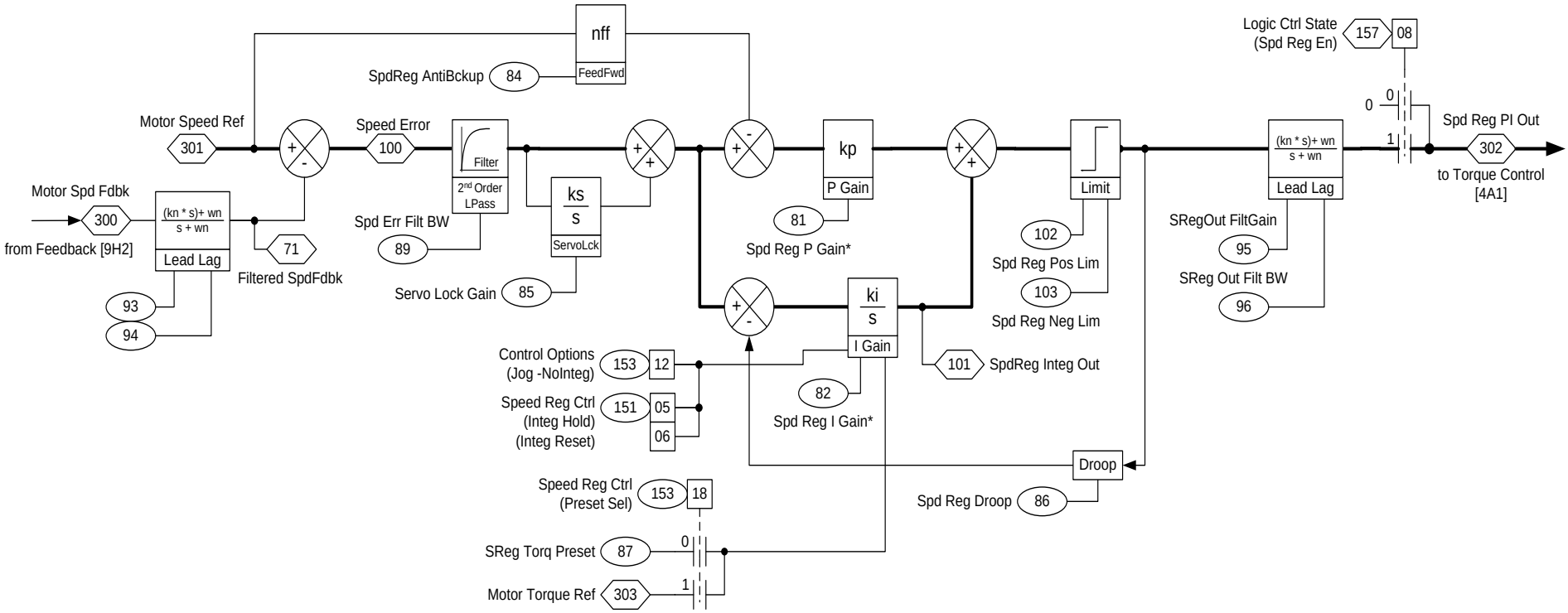


Torque Follower



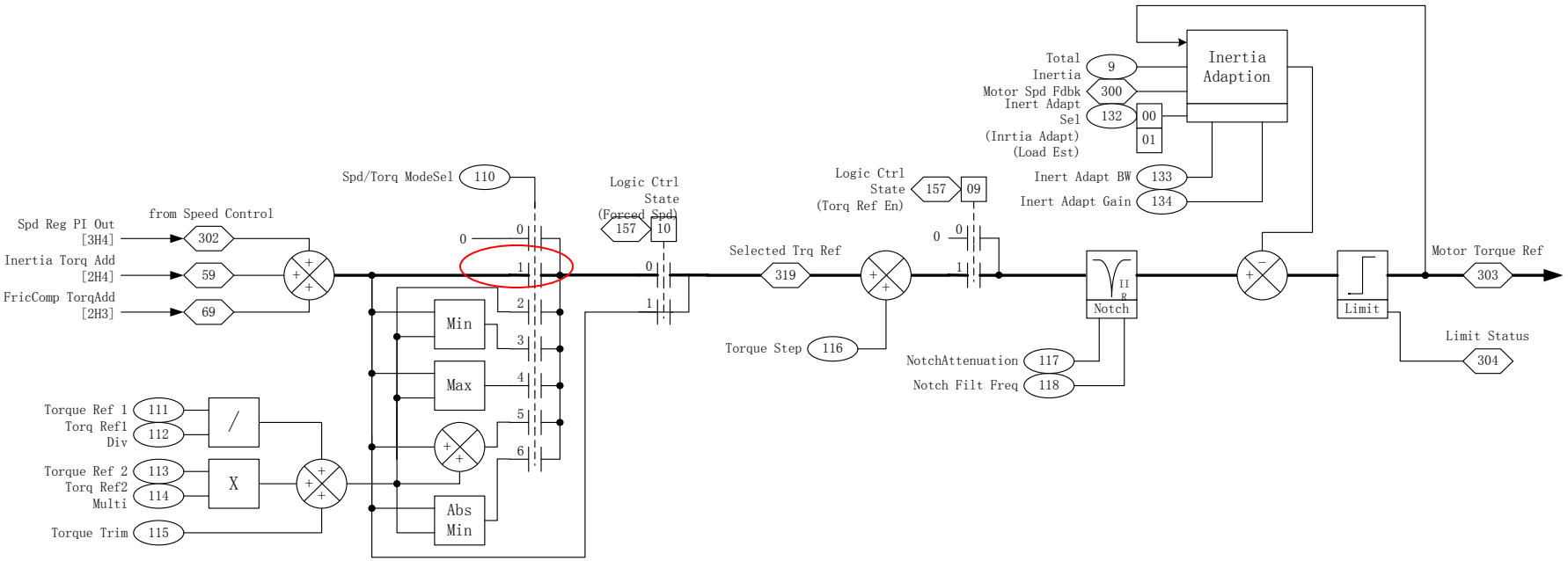
Torque Follower

Speed Regulator

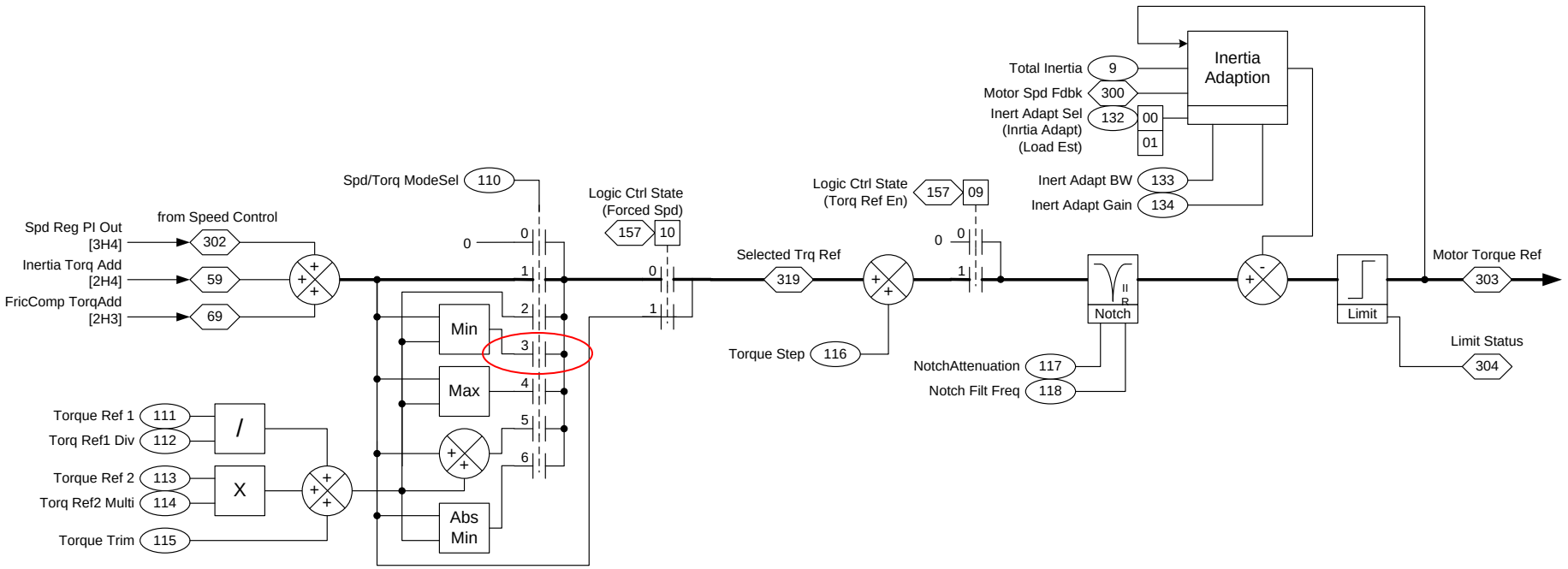


Torque Follower

Torque Regulator

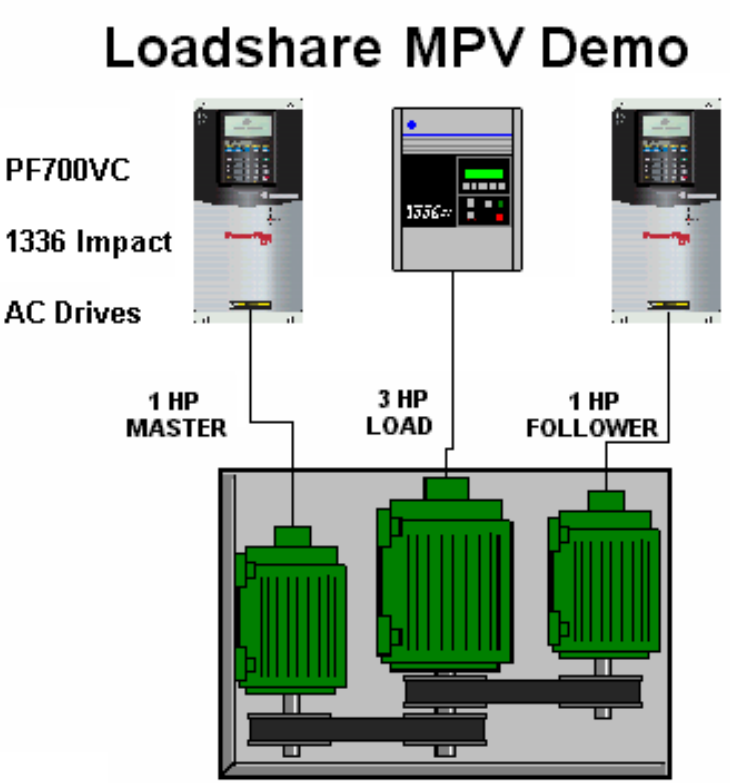


Torque Regulator

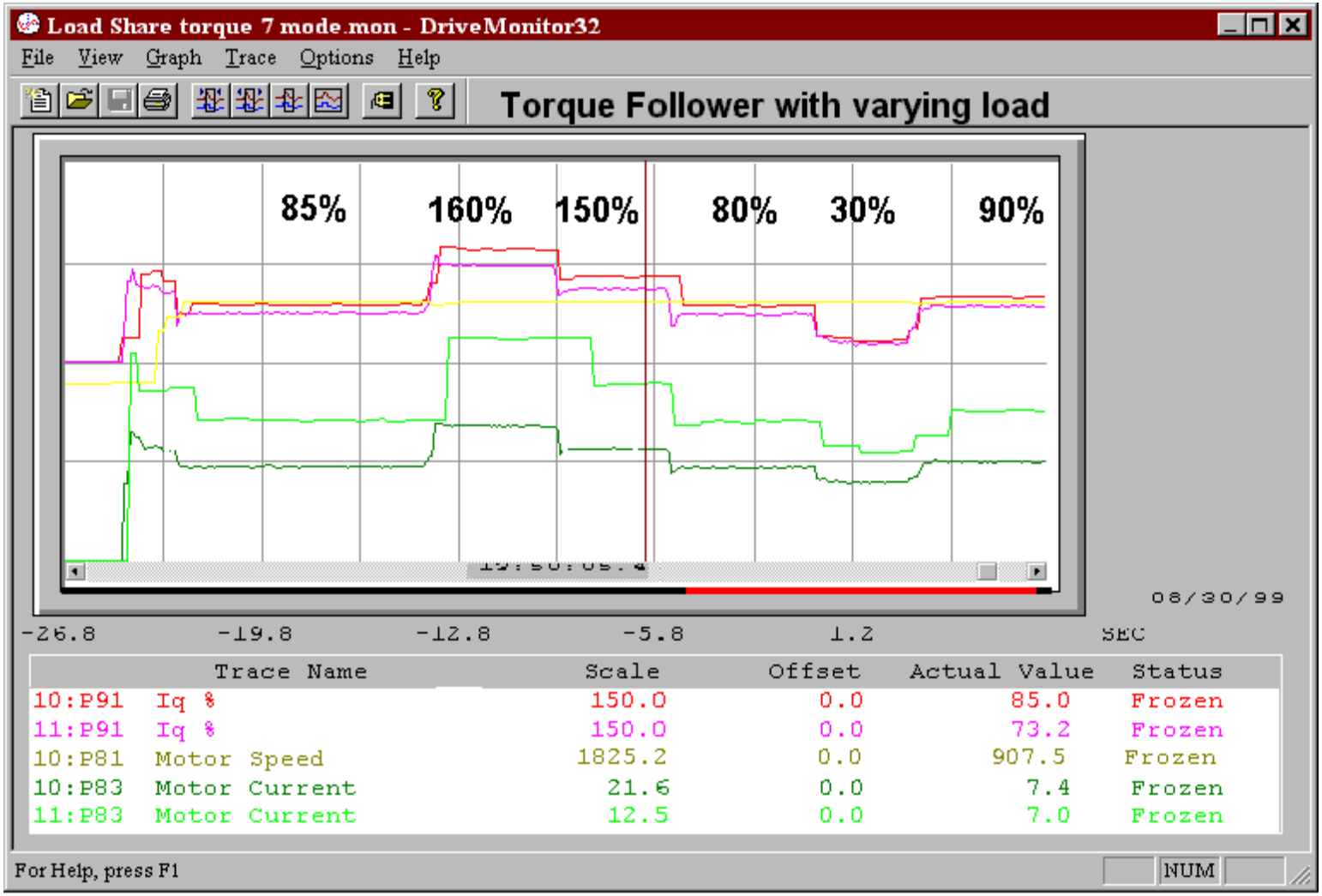


Demo Dyne Layout

- Two 1 HP PowerFlex700 AC Drives coupled by a positive drive belt for load sharing.
- One 3 HP PowerFlex700 AC Drive providing the opposing load.
- Control and shared data between drives over DeviceNet Communications.



Torque Follower



Advantages

- Precise load sharing to act as one drive.
- No speed range limit.
- Do not have to give up speed regulation.
- Min/Max torque reference compare feature eliminates run away
- 可以保证精确的力矩分配效果，使多台电机出力达到单独一台大功率电机的出力效果
- 该方案不会减低速度环带宽，保证系统的快速响应；
- 不会降低电机调速范围，保证低速大扭矩的实现；
- 通过速度限幅，保证电机不会产生超速情况；

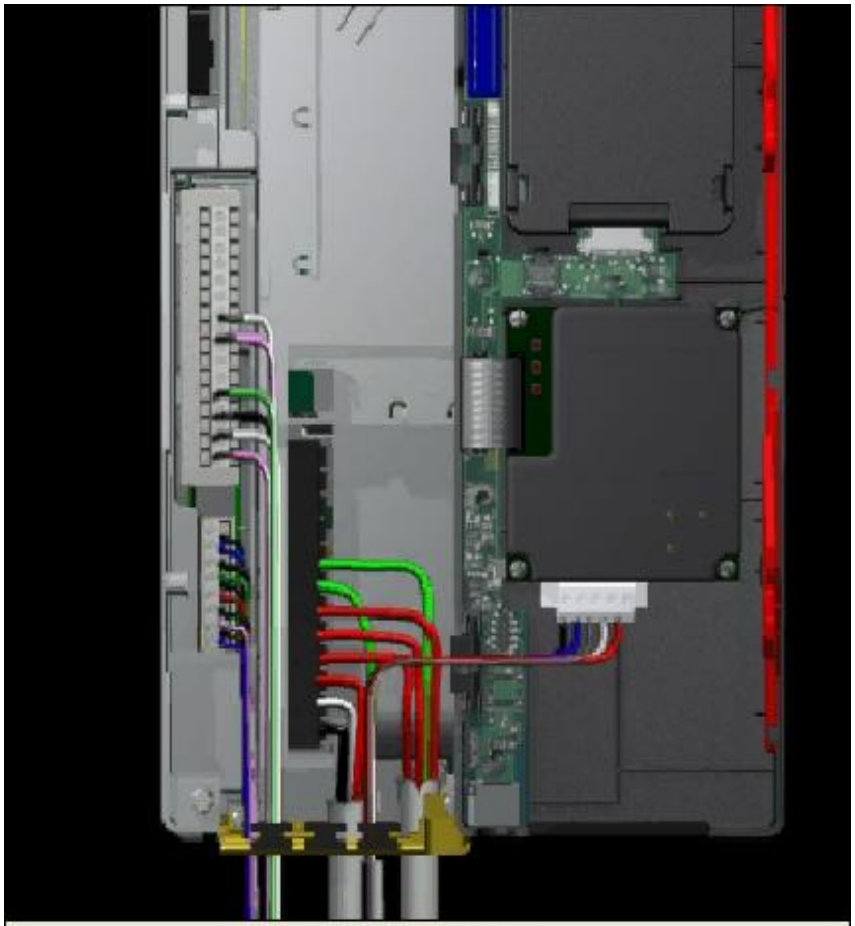
General Guidelines

Use Torque Follower When:

- **Large speed range can exist.**
- **Speed regulation is critical.**
- **Precise Load share.**
- **Need to act as one drive.**
- **Mechanical coupling between motors is stiff or ridged.**

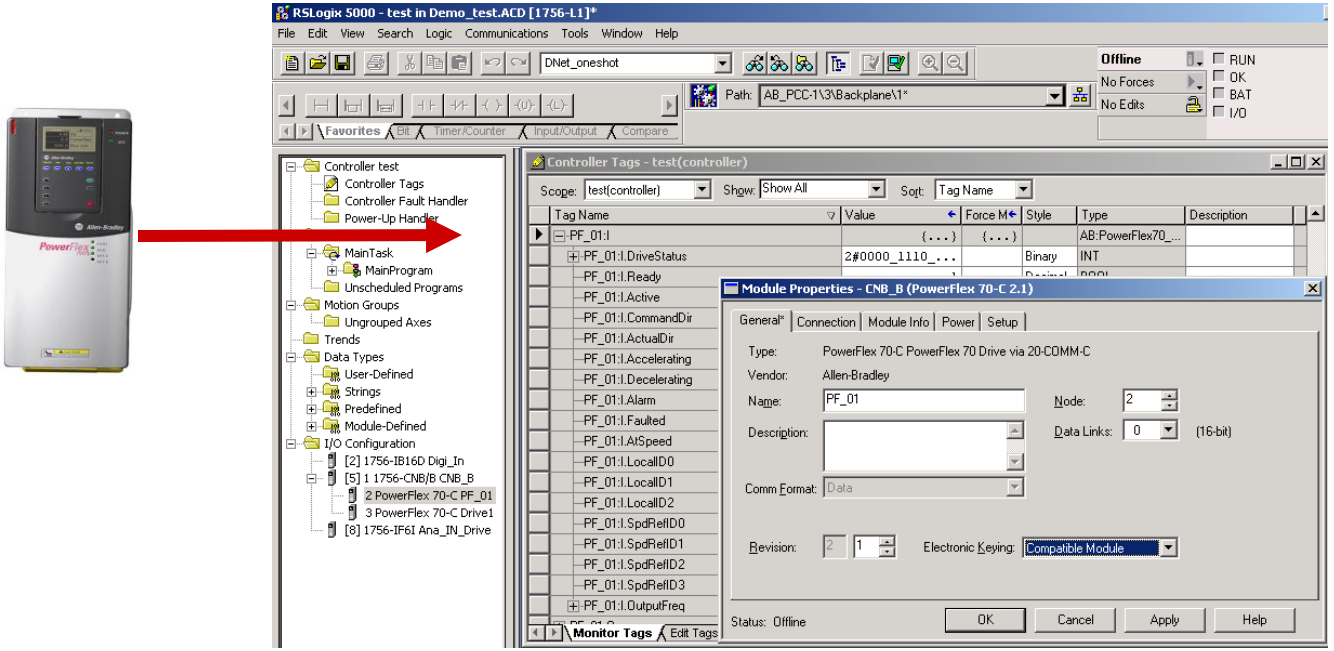
Content

Internal Communication

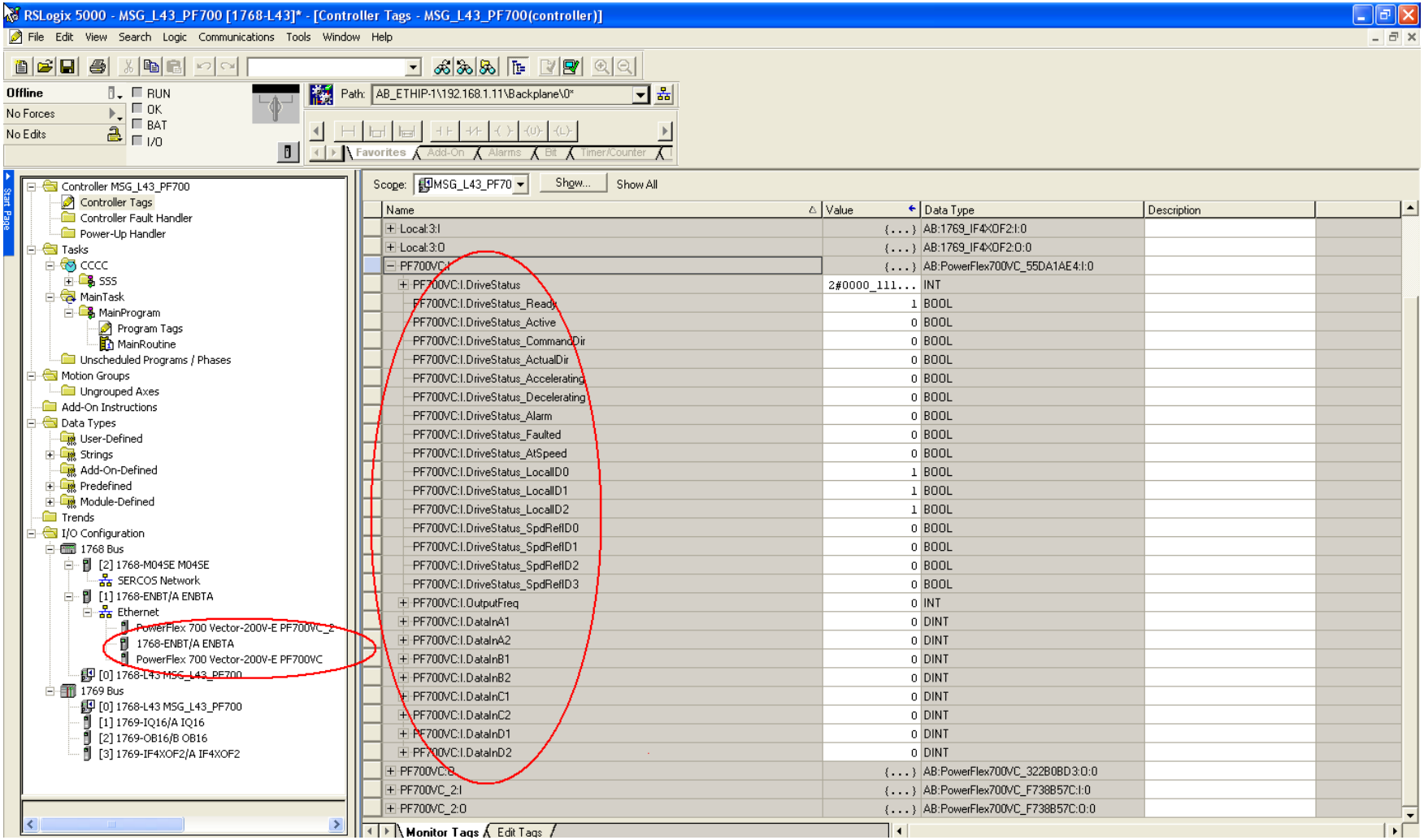


Seamless connection – Software

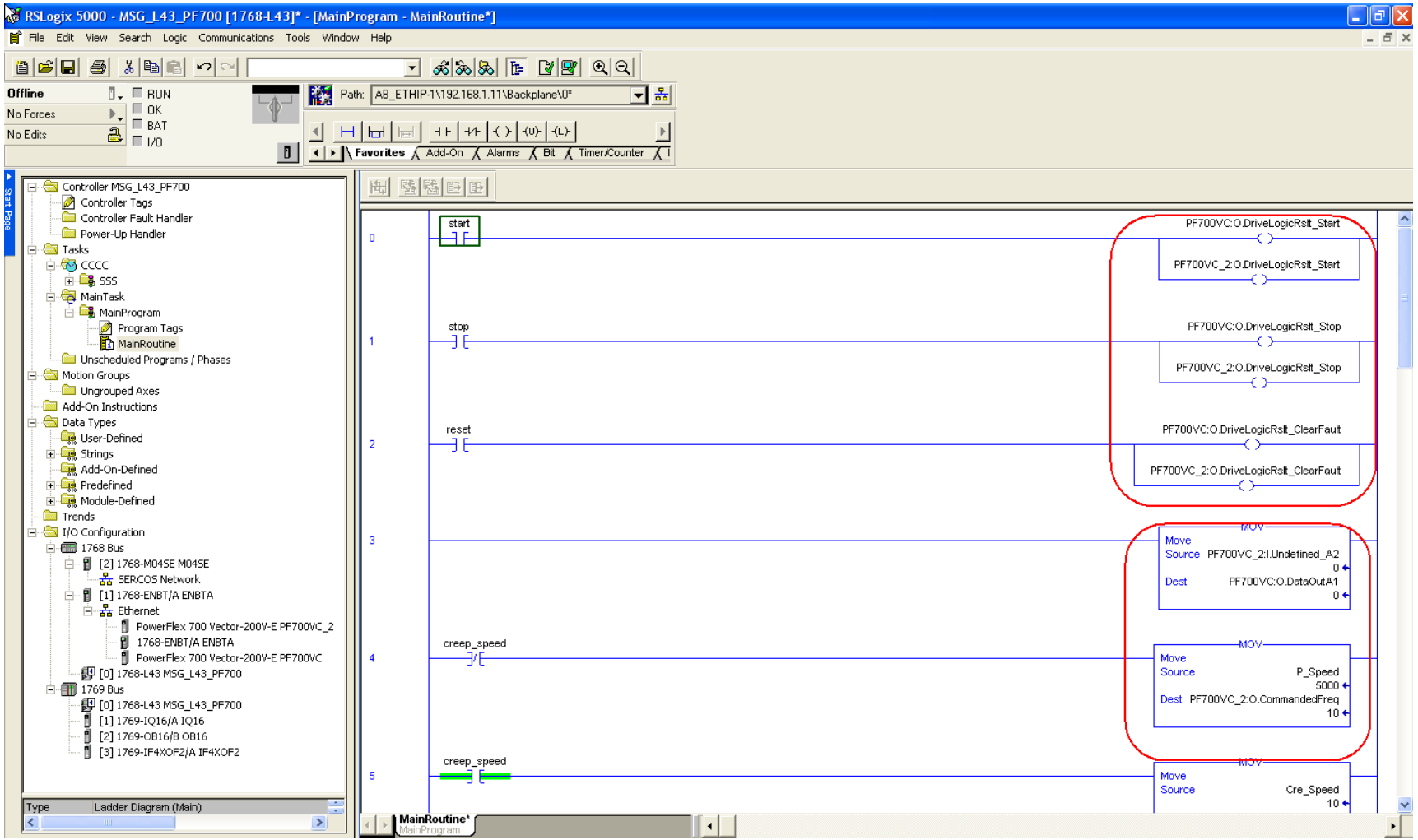
- Drive Integration with RSLogix 5000 Projects
  - Add a drive to your RSLogix 5000 project and the software does the hard work for you:
    - Automatic tag generation for status, command, reference, feedback, and data words
    - Electronic keying for device type and major firmware version helps ensure connection to the correct device and proper device replacement.



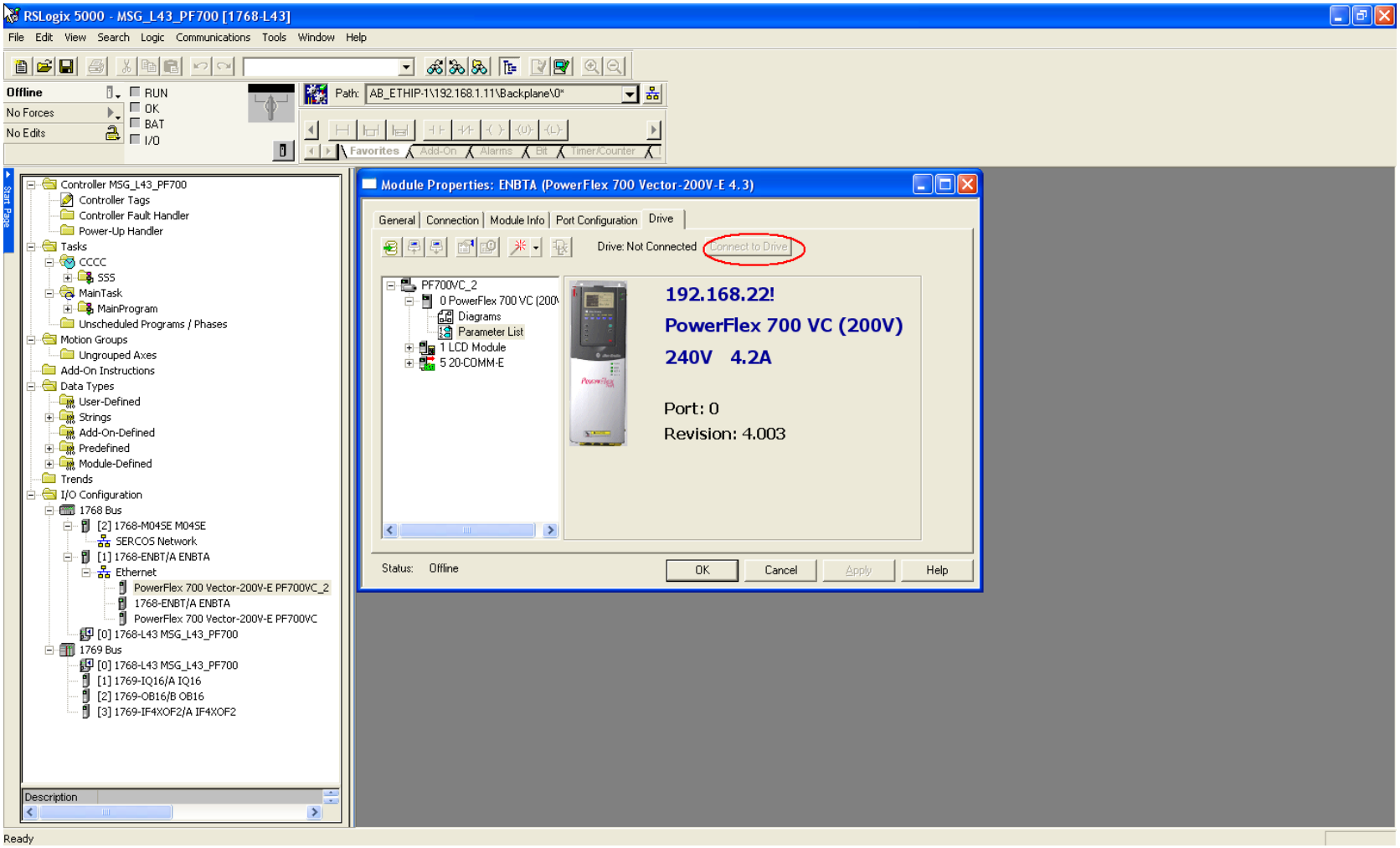
Seamless connection – Software



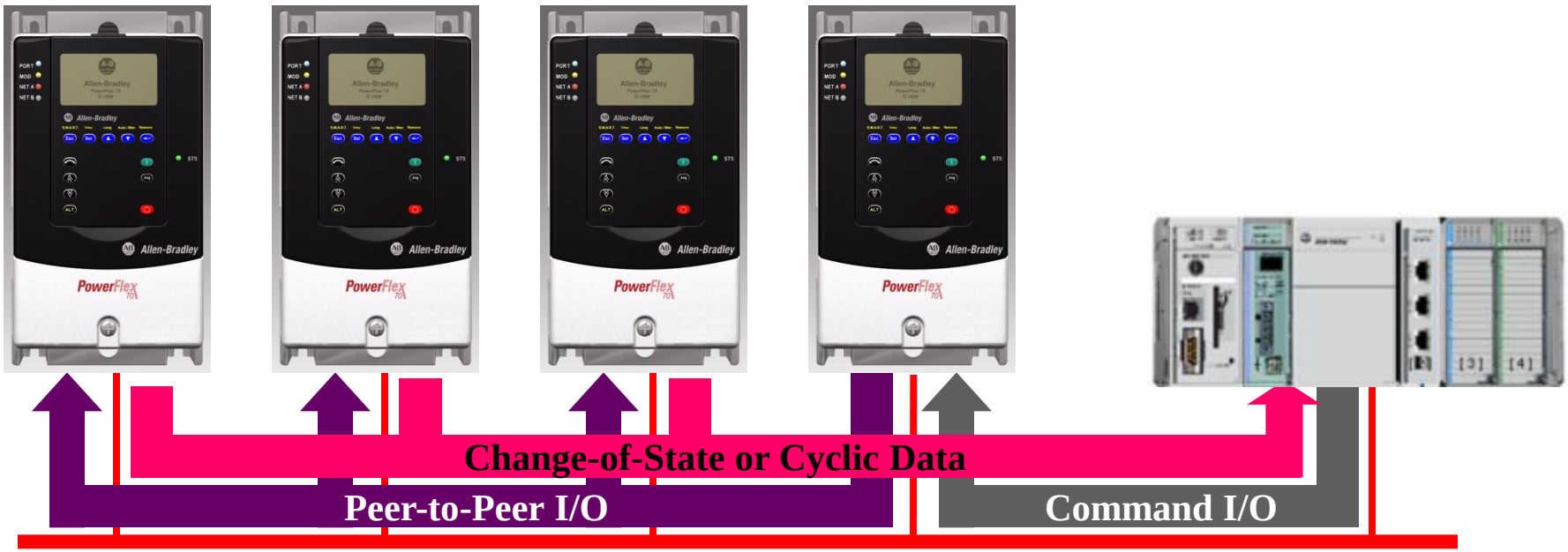
Seamless connection – Software



Seamless connection – Software



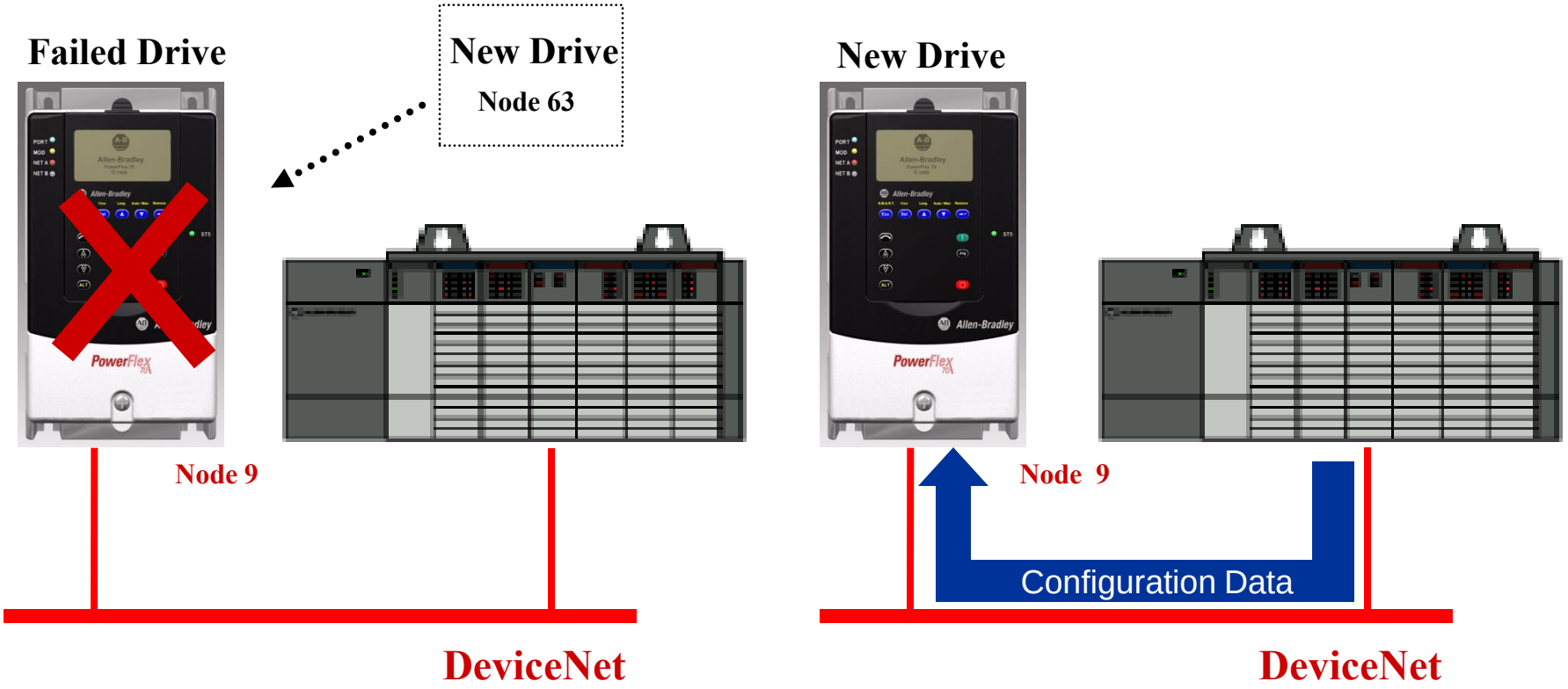
- Enhanced Control Methods
  - Mechanisms for reducing network bandwidth and improving throughput (also makes synchronization possible)



- Master / Slave Control via Peer-to-Peer
  - Configured via adapter parameters
  - Any PowerFlex drive can be the Master
  - Master can be controlled via HIM, Analog signal, PLC, etc.

Easy to Maintain and Repair – Recovery

- Auto Device Replacement (ADR) speeds up the replacement process
  - Eliminates the time spent locating and downloading (or entering) configuration settings to the new drive



Thank You!