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Specifying Processes: Application to Electrical Power Distribution

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Abstract: Problem statement: This study deals with the problem of how to specify processes. Many process specification methodologies have been determined to be incomplete; for example, ISO 9000:2005 defines process as transforming media inputs into outputs. Nevertheless, the author of the Quality Systems Handbook, declares that such a definition is incomplete because processes create results and not necessarily by transforming inputs. Still, it is not clear what description of process can embed transformation of input to output or include creation that leads to results. **Approach:** This problem is important because process specification is an essential component in building projects utilized in such tasks as scheduling, planning, production, management, work flow and reengineering. **Results:** We solve the problem by "opening" the black box in the input-transformation-output model. This action uncovers many possible sources and destinations related to input and output, such as the disappearance, storage and copying of input. It is possible to reject input and also to block output from leaving the process. The approach is based on a conceptual framework for process specification of all generic phases that make up any process and embraces input, transformation, creation and output. The study applies the method in the field of electrical power distribution systems. **Conclusion:** We conclude that the results demonstrate a viable specification method that can be adopted for different types of processes.

Key words: Conceptual model, electrical distribution system, business process, transforming inputs, triggers something, domain performs, specification methodologies

INTRODUCTION

Process specification is becoming increasingly important in building projects utilized in areas such as scheduling, planning, production, management, work flow and reengineering. Studies in this field benefit interoperability and integration among various representations and domains and require development of intuitive semantic primitives that describe the fundamental constituents of concepts of processes.

A number of disciplines have incorporated the notion of process exhibited and this has led to diverse definitions and specification methods such as DFD (data flow diagram), IDEFO (Integrated Definition for Function Modeling) and cause-and-effect diagram. The literature on process definition, specification and analysis is huge and difficult to categorize. According to Warsta (2001), to define, to describe, not to mention to analyze the processes is a laborious task with many perspectives to take into account. Therefore, we highlight some works in this area to show some shortcomings that justify our process specification methodology.

Process is typically defined as a sequence of operations that transforms input into output (Fig. 1). For example, ISO (2005) defines process as "a set of interrelated or interacting activities which transforms inputs into outputs" (ISO 9000, 2008). Process is also described as "a systematic series of actions" that achieve a goal (Juran, 1992), a "structured measured set of activities" to produce a specified output (Davenport, 1992) and "a collection of activities" that creates an output from input (Hammer and Champy, 1994). Moriarty and Thompson (1996) describe a (business) process as follows: "the business process creates and maintains data and ensures its quality and integrity. As user, the business process that uses data to produce its outputs levies requirements on the source business process regarding the quality it requires." We observe the ways in which a process is described in terms of activities such as transform, achieve, produce, create, maintain, ensure, use, … A process has "verb noun" nomenclature …, create .., plan .., sit …, mark .., report ... what is most important about defining the process: the outcome (noun) and the action (verb) (Change Factory, 2010).

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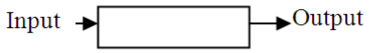


Fig. 1: Diagrammatic description of a process

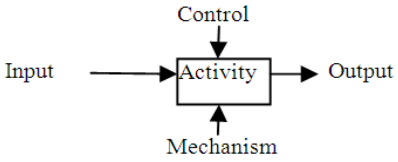
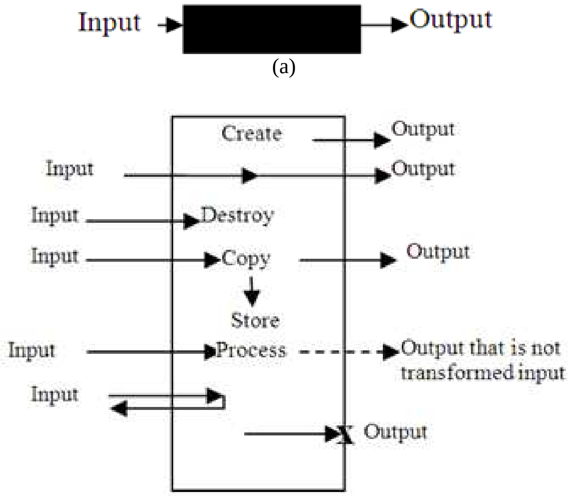


Fig. 2: IDEFO notation to represent a process


(a)

(b)

Fig. 3: Opening the black box in the input-transformation-output model exposes several possibilities of sources and destinations related to input and output

But the verbs seem to specify an arbitrary collection of actions. Is it possible to develop a generic set of these "verbs"? The approach in this study is to develop a description for such a feature.

Moriarty and Thompson (1996) also maintain that "Each process … behaves like a black box, pulling the data it needs from its data store, manipulating it and then returning it to the appropriate data store." The IDEFO notation shown in Fig. 2 is used to depict business processes and data relationships of "control" and "mechanism", where rules constrain process behavior; for example, policies output from the policy formulation process control product tailoring by the marketing process (Moriarty and Thompson, 1996).

This type of process specification is inadequate. One reason is the mixing of semantics, where an arrow represents flows of things (e.g., information) and control at the same time. This is analogous to representing the flows of water and electrical signals (control) in the diagram of water heater devices using identical arrows. It is possible to develop a diagram for process representation that does not increase the complexity of presentation (e.g., few types of arrows). The approach in this study develops such a feature.

Ambiguity can also be seen between process and other notions. For example, it is claimed that "processes are not policies, although they may refer to them. Processes should not define the value of a parameter. For example, 'Reject all bottles of finished product less than 1.07 kg in weight' is better written as, 'Reject all bottles of finished product less than the set weight' and to have a table with today's set weights" (Change Factory, 2010). It seems that the policy can be put in the form of a process where the inputs are bottles that are processed to check their weights, which are then used to make a decision: accept or reject. It seems that this process realizes the policy. The approach in this study clarifies this issue.

While these sample limitations we have raised in defining and specifying processes provide justifications for presenting another view of the notion of process, we focus next on a specific problem raised by workers on the ISO 9000:2005 standards. This problem will be used as a starting point to introduce our approach.

Focus problem: As mentioned, ISO 9000:2005 defines process as transforming media of inputs into outputs. Hoyle (2009), author of the ISO 9000 Quality Systems Handbook, declares that such a definition is incomplete because "processes create results and not necessarily by transforming inputs." Still, descriptions of processes that embed transformation of input to output and creation that produces results are not clear. The "opening" of the black box of the input-transformation-output model, as depicted in Fig. 3a, uncovers many possible sources and destinations related to input and output, as shown in Fig. 3b.

It is possible that output is created, as observed by Hoyle (2009). There are several other possibilities, including disappearance (destruction), storage (not transformed as output) and copying (multiple occurrences, some of which appear as output) of input. In addition, it is possible to reject an input (e.g., wrong address) and to block output from leaving the process (e.g., broken channel or transportation line). It is possible that the input is not transformed into output, rather, that input triggers something (e.g., an input action trigger an output signal).

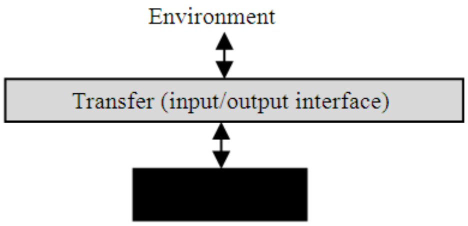


Fig. 4: Descriptions of input and output

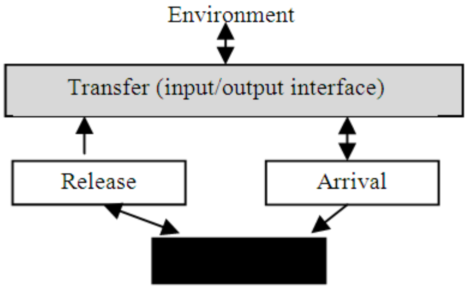


Fig. 5: Received things may not be accepted and released things may not be transferred

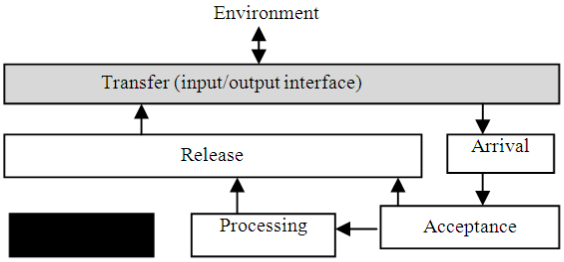


Fig.6: Creation

This study proposes an alternative approach to process description that does not require ordering of and consequential relationships between input and output. Additionally, it covers the location of the source of output (input or creation) and handles the possibility of rejecting input and blocking output. This development benefits the tasks of defining, describing and analyzing processes in many application areas.

The model to be described next has been used in many applications (Al-Fedaghi, 2011). However, we develop it here in a new way.

Structuring process: As mentioned, the ISO 9000:2005 definition of process as transforming media of inputs into outputs has been declared incomplete (Hoyle, 2009) because “processes create results and not necessarily by transforming inputs”. We describe the notion of process in a more complete way. So what does a process do?

A process with input and output: All known definitions of process include input and output as essential components of any process. Conceptually, input and output make up the interface with the environment. This is classically represented as shown in Fig. 3a. This representation is deceptive because it does not indicate that input and output have a single conceptual function: transfer. That is, input and output are those parts that interface with the environment, as represented in Fig. 4. Figure 3a is also a very special case of interfacing that embeds many types of transfer, some of which are shown in Fig. 3b, which implicitly expresses consequence (an input results in output) and sequence (input, then output). It is possible that items that are output were not input, but rather were created internally, as noted by Hoyle (2009). It is possible that things that are input are destroyed, copied, or stored and may or may not result in output.

Arrival and release: Another point to be taken into consideration besides the transfer phase is that not every incoming transferred thing is accepted and not every released thing is transferred, as shown in Fig. 5. Things (here called flow things, e.g., information, data, money, orders for goods) may be returned upon arrival. For example, a package may have the wrong address or an order is incomplete, thus it may not be accepted and will be returned to sender. Similarly, released flow things may not be transferred for many reasons; for example, the channel is down. Then either the channel works again, or the waiting released flow thing is returned to sender, destroyed after a certain period of time, or so on.

Acceptance and processing: Assuming that arriving things are not rejected and released things are transferred, two phases can be added: acceptance and processing. Acceptance means entering the system after arrival. They arrived flow things may be released, as in the case of give-and-take processes (Fig. 6), or the accepted things are processed in some fashion, such as the case of changing their form; for example, a message is translated. Processed things may be released but never returned to the acceptance phase. How do they again become accepted arriving flow things when already past the arrival and acceptance phases and moved to the processing stage?

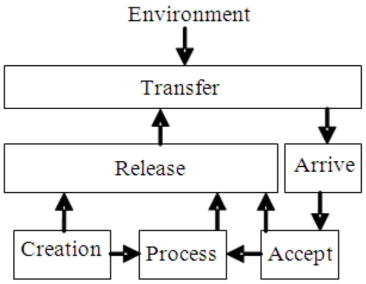
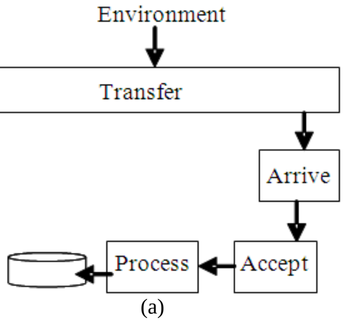


Fig. 7: Flow system



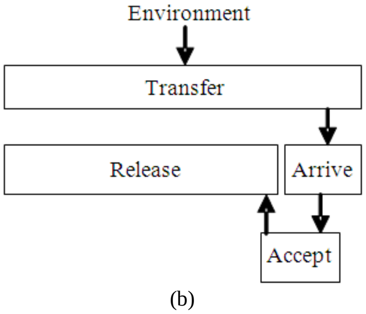


Fig. 8: Two possibilities for accepting input

Creation: Things may not arrive from the environment, but, rather, can be created internally. After creation, a flow thing may be processed or released, as shown in Fig. 7. Figure 7, called a flow system, depicts a process of things that flow, e.g., information, data, signals, money, materials... These things that flow, as mentioned, called flow things, are things that are created, are transferred, arrive, are processed and are released, according to the diagram in Fig. 7.

Flow system as a process: A flow system consists of a maximum of six generic (mutually exclusive) phases and there are possible secondary phases such as storage and copying. For example, information can be created and stored, it can be released and stored (e.g., channel is down), it can be processed and stored. Thus storage is not a generic phase.

A Flow thing Model (FM) involves a topological mapping of different flows of flow things using flow things and the mechanism of triggering that permits flows to trigger each other, as described in the next section on transformation.

We propose defining a process as a flow system. Certainly, the flow system includes input and output. It also satisfies the requirement of Hoyle (2009) that “processes create results and not necessarily by transforming inputs.” Additionally, the flow system completes the conceptual picture of a process by including Arrival and Acceptance and Release and Transfer.

The processing phase in the flow system indicates transformation that changes the flow thing without losing its identity, as will be discussed next. For example, a message can be translated into another language and a number can be changed from decimal to binary. The six phases in the flow system can be thought of as states of the flow thing, just as in physics, molecules of water are arranged in three mutually exclusive states, that is, solid, liquid and gas.

Transformation: According to Hoyle (2009), “inputs are not transformed but used and outputs are not transformed from inputs but created.” In FM an input means transfer, arrival and acceptance of a flow thing. There are many possibilities for the progress of such an input, for example: Processing (e.g., changing its form from decimal to binary) and storing they arrived flow thing, as shown in Fig. 8a. Release of the arrived flow thing, e.g., a dumb terminal that receives and sends signals, as shown in Fig. 8b, triggering the creation of a new flow thing. Triggering in FM, denoted by a dashed arrow, may be a “jump” from one flow to another. The two flows may be in different flow systems, as discussed in the notion of transformation that follows.

In FM there are two types of flow that can be conceptualized as transformation:

- Flow things that enter the system may be processed and then output (released and transferred)
- Things that are created internally may be processed and then output (released and transferred)

In this context, the meaning of transformation can denote a change made to the flow thing without changing its identity, as in the case of a shift in form. For example, in geometry, rotation, reflection, resizing, coloring, … are all transformations (processing) of this type. The thing flows into the process as an input (through the transfer interface), arrives, is accepted and is processed.

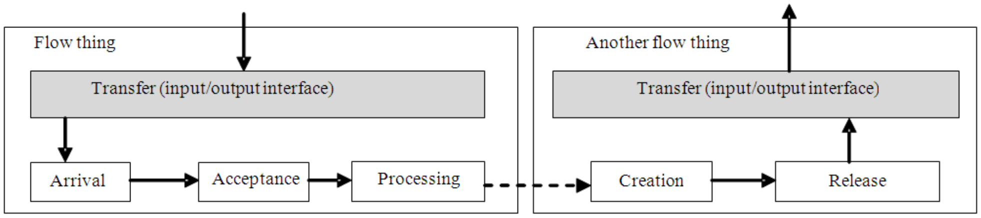


Fig. 9: Triggering to create another thing

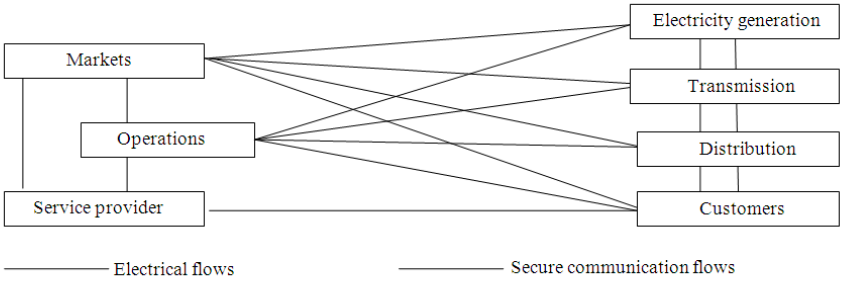


Fig. 10: Conceptual description of electric power generation, transmission and distribution system (drawn with a different orientation from NIST, 2010)

Another meaning of transformation indicates a basic change of character and little or no resemblance to the past configuration or structure Business Dictionary. Examples of this include the transformation of raw materials into finished products (e.g., a luxury vessel) and the transformation of organic material into petroleum. This type of transformation involves a certain kind of flow thing that triggers the creation of another flow thing kind, as shown in Fig. 9, where triggering is represented by dashed arrows.

According to the development in this section, a process has six primary phases that reflect handling of flow things that either come from the environment or are created internally. This conceptualization of a process shows that it has several initial and final stages (e.g., transfer, arrive, …, transfer; create, process, …, transfer), in contrast with the classical view of definite initial (input) and final (output) stages.

In the next two sections we demonstrate the advantages of our method of process specification in the area of control of electrical power distribution (Mansour *et al*., 2009). First, the next section examines a conceptualization method presented by the US National Institute of Standards and Technology (NIST, 2010) in fulfillment of its primary responsibility under the Energy Independence and Security Act of 2007 (EISA) to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems… (18EISA Title XIII, Section 1305). This examination will provide an opportunity to scrutinize the NIST's "conceptual architectural reference model" as an example of an important and very recent diagram-based description that involves many processes. Our focus will be on a very high-level representation of the domains of electrical generation, transmission and distribution. Second, this examination is complemented by sublevel details of a "protection scenario" in a power distribution system published by Wei and Chen (2010).

Conceptualizing a power system: NIST (2010) released a conceptual architectural reference model that supports "planning and organization of the diverse, expanding collection of interconnected networks that will compose the Smart Grid" (NIST, 2010). The Smart Grid is a "complex system of systems for which a common understanding of its major building blocks and how they interrelate must be broadly shared." The model has been developed "to facilitate … [a] shared view ... [provide] a means to analyze use cases, identify interfaces for which interoperability standards are needed and to facilitate development of a cyber security strategy." In this context, NIST presents the diagram shown in Fig. 10 as a high-level conceptual description of a system of electric power generation, transmission and distribution. The following account of the system's components is summarized and certain parts copied with omissions from NIST (2010).

Electricity generation is the process of creating electricity from other forms of energy. The Customer domain provides control and information flow between the Customer and the other domains. There are three types of customers within the Customer domain: industrial, commercial and residential. All three domains have a meter actor and a gateway. The gateway enables applications such as remote load control, monitoring and control of distributed generation, in-home display of customer usage, reading of non-energy meters and integration with building management systems.

The Operations domain performs ongoing management functions such as network operation, network operation monitoring, network control, fault management, operation feedback analysis, operational statistics and reporting, real-time network calculation and dispatcher training. The Markets domain performs pricing or balances supply and demand within the power system. The Service Provider domain includes the organizations providing services to electric customers and utilities. It communicates with the Markets, Operations and Customer domains.

The Distribution domain is electrically connected to the Transmission domain and the Customer domain at the metering points for consumption. The Distribution domain also communicates with the Operations and Markets domains. Distribution networks are now being built with interconnection, monitoring and control devices and distributed energy resources capable of storing and generating power. The Distribution domain may include capacitor banks, sectionalizers, reclosers, protection relays, storage devices and distributed generators.

Transmission is the transfer of power from generation sources to distribution through multiple substations. It is electrically connected to the Bulk Generation and Distribution domains, as well as communicating with the Operations and Markets domains. The Transmission domain may include remote terminal units, substation meters, protection relays, power quality monitors, phasor measurement units, sag monitors, fault recorders and substation user interfaces.

We propose that an FM-based depiction of the system provides a foundation for a simplified diagram (e.g., for nontechnical presentation) and, at the same time, for more detailed specifications at lower levels. We emphasize the model's general objectives:

- To facilitate … shared view
- To provide a means to analyze use cases
- To identify interfaces for which interoperability standards are needed
- To facilitate development of a cyber security strategy

This feature of FM is general. ISO 9000 (2008) standards use a process-oriented approach, where a system is viewed as a single large process that receives many inputs to generate many outputs. According to ISO 9000 (2008), the benefits of such an approach include integration and alignment of processes, effectiveness and efficiency, confidence, transparency, consistency, prioritization, involvement and the clarification of responsibilities. Even though the contexts of the SO and NIST projects are different, their objectives are similar. In the context of this study, we focus on the best way to describe systems. We propose FM as a uniform mechanism that can be applied at all levels of such a venture. We start from an FM-based diagram, proceeding upward to simplify it and downward to any level of detail.

Examining Fig. 10, one can question the Operation domain: Operation of what? It seems that Operation refers to the operation of power generation, operation of transmission, operation of distribution, … Thus it seems that Operation is a redundant second-level domain that takes on the management aspects of other domains. Consider Distribution, as will be described in detail in the next section: operation monitoring, fault management, operation feedback analysis, operational statistics and reporting, … are integral parts in a description of Distribution. Operation in Fig. 10 is an abstraction, while all other components are distinguishable parts in reality. This mixture creates a muddy conceptual view. As we will see in the next section, faulty voltage would trigger (signal) information sent to the control center, which would send a maintenance team. The notion of Operation in the FM-based description is an integral feature of the flow.

Another point is that, from the FM point of view, Fig. 10 does not adopt the principle of separately identifying different flow things. For example, "secure communication flows" may mean flows of different types of information and signals. In addition, the directions of flows are not presented. The point here is that Fig. 10 is conceptually sketchy and can be reconstructed as a byproduct of development of a more comprehensive specification of the system of electricity generation, transmission, distribution and customers. Such a description of a system can be viewed like the architectural blueprint for a high-rise building where floors and rooms are clearly identified along with separate flows of electricity, water and gas. Such a blueprint can be simplified by eliminating some details, but never by eliminating elements in such a way that the design would be flawed, such as by mixing electrical lines with those of water.

As an example of the FM approach, the next section draws a complete picture of the processes involved in the power distribution. The resulting diagram can be simplified to the desired level. From similar diagrams for other systems it is possible to draw a general high-level description of interactions between them.

Automated power distribution: This section contrasts the FM-based method with a sample representation of high-level specification of a recent "protection scenario" in a power distribution system published by Wei and Chen (2010).

Electrical power distribution is typically managed by substation automation systems that employ computerized systems to improve operation and maintenance effectiveness with minimal human intervention (McDonald, 2007). Automation in this context employs intelligent open systems with advance information and communication technology such as relational database systems, multitask operating systems and graphical display technology.

A typical power distribution automation system consists of Intelligent Electronics Devices (IEDs) and a communication network based on an ISO model. An IED is any device incorporating one or more processors with the capability of receiving or sending data/control from or to an external source (e.g., electronic multifunction meters, digital relays, controllers) (Smart Distribution System, 2011). The system also includes Supervisory Control and Data Acquisition (SCADA) systems at the control center that are used to collect status and measurements from distribution equipment in substations for the purpose either of bookkeeping or of responding to difficulty occurring at any feeder or local substation. The distribution system also includes traditional power system components such as substations, transformers that increase/decrease voltage/current level, feeders connected to different loads in the area surrounding the substations and circuit breakers. Relays are logical elements that process inputs (mostly voltages and currents) from the system/apparatus and, when a fault is detected, trigger the electrical circuit breaker to trip.

For electrical power to reach loads in various locations, the process starts when power produced by an electrical generator is raised in voltage for the long transmission journey. This power is conducted over transmission lines to switching stations located in a specific load area served. When the incoming power reaches the switching stations, it is stepped down in voltage for transmission in smaller quantities to the substations in the local load areas. This incoming power is lowered again in voltage for distribution over a local area. Each substation feeds its local load area by means of primary distribution feeders. This flow of electrical power may be visualized by comparing it with the flow of water. Whereas water is made to flow in pipes, electrical current is conducted along wires. To move a definite amount of water from one point to another in a given amount of time, either a large-diameter pipe is used and low pressure applied to the water to force it through, or a small-diameter pipe is used and high pressure applied to the water to force it through. While doing this, it must be kept in mind that when higher pressures are used, the pipes must have thicker walls to withstand that pressure (Pansini, 2005).

When electrical power reaches a substation terminal, its current value is stepped down by transformers. It then travels through the substation transmission line, passing through a circuit breaker to confirm the validity of its voltage/current level, when it is passed to the assigned feeder relays through "step-down voltage and current transformers." It is then sent to the relays, where the resulting voltage and current are transformed to digital voltage and current signals and compared to a preset value available at the protection device.

Under normal conditions, the resulting data would be transferred to the IEDs and then to the workstation. There, the data are stored and/or further processed and transferred to the control center for storage and further processing. In the case of a short circuit, overload, or any other fault that is temporary, it is automatically fixed by the automation devices, or if permanent, is fixed manually by a maintenance team. The data are transferred to the IED as a trip signal to trigger an electrical current that will activate the circuit breaker. In some cases if there are reclosers in the substation feeder, the circuit breaker is turned off automatically after isolating the faulty equipment and the electrical power flows through the feeder. In other cases the fault in the feeder is isolated but not automatically recovered and must be fixed manually. At the same time, the data received by the IEDs are processed and transferred to the workstation to issue an alarm on the monitor locating the cutoff feeders and provide detailed data concerning the disoperation of the faulty equipment. The alarm message is transferred to the control center, where a group analyzes the received data and issues specific instructions to the maintenance team sent to the faulty feeder. The maintenance team then provides a detailed report that will be stored in the control center archives.

Motivational sample: The distribution system is the most visible part of the supply chain of a power system and as such the most exposed to the critical observation of its users. It is, in many cases, the largest investment, in terms of maintenance and operation expenses and the object of interest to all agencies involved. Building a conceptual model for such a system provides an initial phase for describing and understanding its structure and functions. Most power distribution systems nowadays focus on IEC61850 Standard Protocol (EISA, 2007; Wei and Chen, 2010), used to connect a distribution substation with workstations and a control center using the ISO communication model.

An example of a high-level view of automated power distribution system schemes (Fig. 11) shows a protection scenario in a power distribution system published in Wei and Chen (2010). The figure depicts the relationships among protection, logical device, IED and LN XCBR and Logical Node XCBR represents the common information in a real circuit breaker (Wei and Chen, 2010).

Figure 11 lacks a descriptive explanation of different types of signals involved in the system and the relationships between various components and protection devices. It does not differentiate between different electrical power values used in the power system due to use of step-down transformers, or between the digitalized current and voltage signal in the relays that are transferred from the relays in the feeder to the IEDs. The description also does not depict how exactly the digitalized voltage and current signal are used, or how the cycle is completed when a circuit breaker in the feeder is not switched off automatically.

There are arrows of different thicknesses, colors and dashing. They seem to represent flows of information signals and electricity. Some have a label, some are arranged in parallel groups. Various components of the system are represented with different shapes such as boxes, crosses, circles and cross bars. The boxes includes devices such as LN XCBR and functionality such as protection, network and loads. The best that can be concluded by looking at Fig. 11 is that it is a sketch of the system that can be understood by certain technical people. It is not based on any systematic or standardized conceptual specification characterized by precision and simplicity.

At this level of detail, the flow thing model presents a more refined conceptual representation that can be used as a foundation for more detailed specification for technical and nontechnical persons. From the FM-based description, a brief sketch can be developed that is more systematic than Fig. 11. In addition, a more detailed description specification can be built, as illustrated in Fig. 12.

Conceptualizing power distribution: Alternatively, we propose building a conceptual model for power distribution systems. A similar model can be built for other systems, such as the generation and transfer system shown in the NIST conceptual representation shown in Fig. 10. Our model offers a fundamental depiction that can be used as a means of communication and understanding instead of sketches such as those shown in Fig. 10 and 11. It is a formal or semiformal description that captures relevant aspects of the physical world.

According to Plotkin (2003), Electrical, chemical and mechanical engineering are applications of science in which Conceptual Systems (CS) are developed and then Physical Systems (PS) is constructed from them. An example of such a CS is an electrical circuit diagram. Such a diagram is a CC (conceptual systems based on CS) and contains standard symbols representing certain physical objects, such as switches, compactors or diodes.

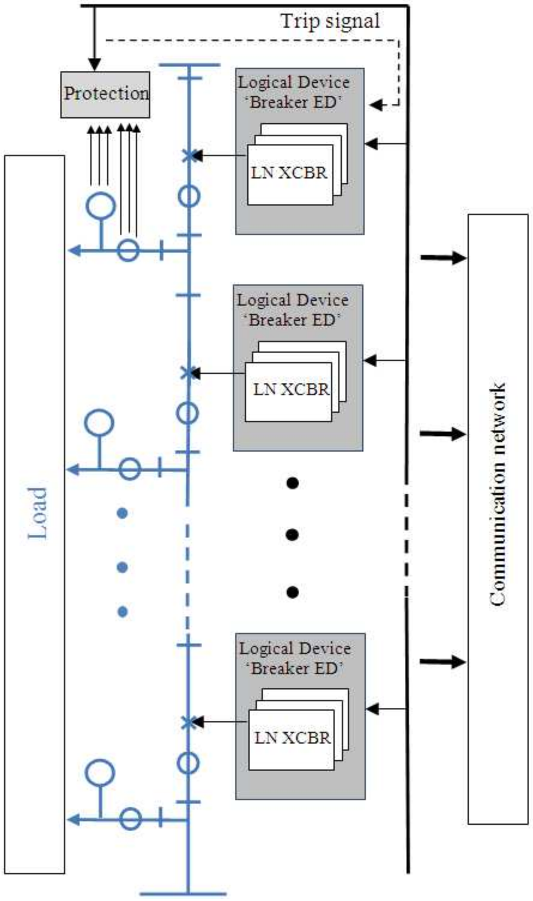


Fig. 11: Electrical power distribution system scheme (from Wei and Chen, 2010)

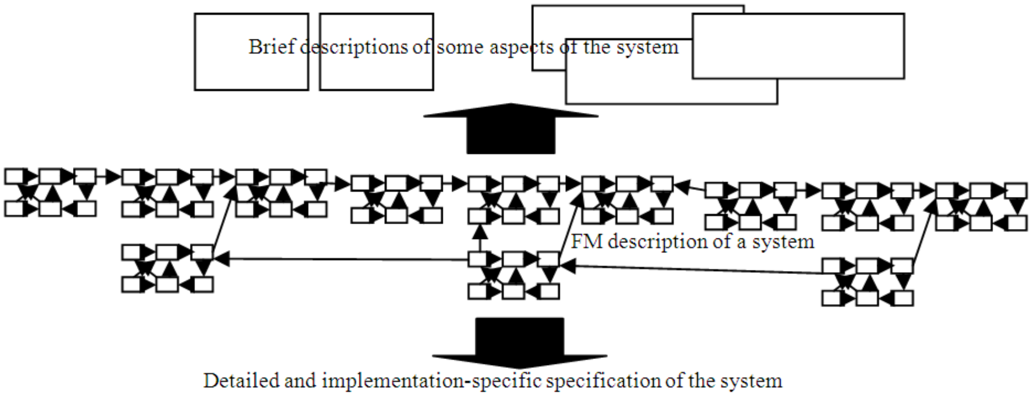


Fig. 12: FM-based description of a system serves as a foundation for brief and more detailed specification.

In our case, we draw a conceptual diagram at a descriptive level, supplied with views of processes directly from reality.

Many diagram-based conceptual descriptions become cumbersome because there is no restriction on the basic conceptual apparatus. Consider a logical operator such as AND, OR and other control of flow mechanisms such as synchronization that can be erected when flows join together and when timing needs to be coordinated. In the flow thing model, such notions come, if needed, in the second level of specification. These tools are "unnatural" controls from the flow point of view. Imagine a civil engineer who draws a map for a territory including a river system. First, the engineer draws a topographic model, including streams, directions, joins (without, for example, worrying about the type of joining, e.g., relative speed of currents) and branches (e.g., relative division of water; one branch may have a dead end). Then, the engineer inspects and decides about damming, channelization, diversion, bridge construction and sand or gravel mining. In addition, electrical engineers lay a map of electrical lines as an initial diagram of a building, where the details of points of meeting/ending lines are left for a second round of design overlaid on the initial map.

FM-based conceptual model for power distribution: Figure 13 shows an FM-based description of an electrical power distribution system. The electrical power (electricity) arrives at the terminal of the power distribution system (circle 1) through the transmission line connecting the distribution substation to the power generation system.

After a small delay-almost unnoticeable in nanoseconds-the received electrical power is released. The received electrical power triggers creation of new electrical power with lower current value in the step-down current transformer (circle 2). This resulting electrical current is released from the transformer and flows through the circuit breaker, if the level of current/voltage flowing in the feeder is equal to or below a certain preset value. Then electrical current flows (circle 3) to one of the feeders. The received electrical power in the feeder is tested by the protection device in the feeder before it is transferred to the load (e.g., house, factory, building). This could entail a certain delay time (not included in the FM description at this level of specification) during which the electrical power flowing to the Load remains in the received state (circle 4). To check the status of received electrical power, the protection device in the feeder triggers creation of yet another electrical current and voltage (lower values) in voltage and current step-down transformers, respectively. The electrical current and voltage trigger the creation of digitalized current and voltage in the relays of the protection device (circles 5 and 6) The resulting data are processed in the protection device by comparing their values with preset values. Every time the protection device performs this step, it transfers the resulting data to the IED device. In case the comparison results in a short circuit or overload, current data in the IED processor trigger electrical current/voltage creation (circles 7 and 8) that opens the circuit breaker to disconnect the faulty part or the entire feeder from the distribution system until the problem is resolved, either by automatic attempts at recovery or by a maintenance team sent to the site Distribution Grid.

At the same time, the resulting data would be stored and transferred through the communication network to the workstation. In the workstation, the received voltage/current data trigger the alarm system in the monitor screens of the workstation (circle 9).

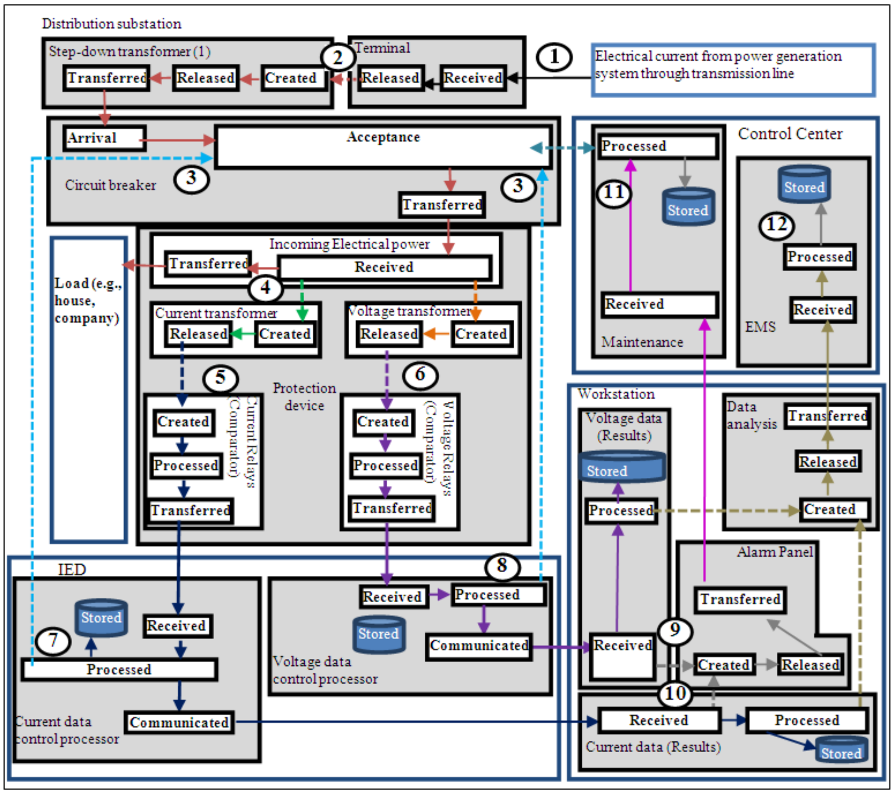


Fig. 13: Detailed FM-based electrical power distribution system

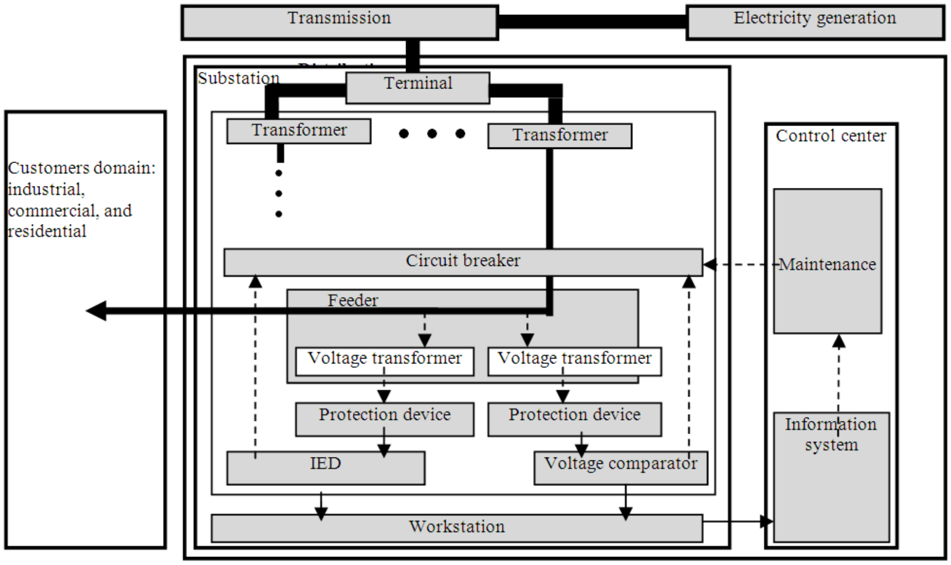


Fig. 14: Conceptual description of power generation, transmission and distribution system

This is in case of permanent damage that cannot be automatically fixed (Kezunovic, 2006). Concurrently, these data are processed in the database of the workstation and archived separately as voltage and current data. The processed current/voltage data could be combined to trigger creation of power data (circle

10) to be stored and transferred to the control center database. In the control center, the power data are processed and stored in the Energy Management System (EMS) of the control center as reference for future use (circle 12) (Wu *et al*., 2005). In case the faulty device in the feeder does not automatically react to clear the problem in the feeder, the alarm system would transfer the data (location, type of fault) to the control center to be process-analyzed, providing specific instructions for the maintenance team sent to the feeder location. A repair report is created, processed (circle 11) and stored in the database of the maintenance department for future reference.

Sample of brief sketch: Figure 14 shows a conceptual description of the system that can be extracted from the specification in the previous section. The system includes five types of flow things:

- High-voltage electrical signal from power plant through transmission line
- Low-voltage electrical signal produced by transformers
- Information, e.g., data from workstation in substation to control center
- Signals, e.g., from IED to circuit breaker
- Actions when emergency team works

The flows of these flow things may trigger each other.

CONCLUSION

This study examines the problem of how to specify processes. It proposes “opening” the black box in the input-transformation-output model to uncover many possible sources and destinations related to input and output. The approach is based on a conceptual framework for process specification of all generic phases that make up any process and includes six phases: transfer, creation, processing, release, arrival and acceptance. The study applies the specification method to an electrical power distribution system. The resulting description demonstrates the viability of the methodology that can be adopted for different types of processes. The conceptual description can act as a foundation for brief sketches as well as for more detailed specification of the system. It is simple in the sense that it is produced by repeated application of the six-phase depiction of processes with triggering and flows among them.

Future work involves building conceptual descriptions of other systems, including transmission and generation in electrical power systems. Such a venture would produce a blueprint or conceptual map similar to blueprints of construction projects. Additional work can pursue application of the FM-based methodology to other engineering descriptions such as requirement engineering (Oshkovr *et al*., 2008) and robotic engineering.

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